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ISSUED QUARTERLY

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THE Association was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of 900 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

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This Association has at least eight regular meetings each year, of which five are held in Boston, one in northern New England, one in southern New England, and one, the annual convention, held in September on such date as the Executive Committee may designate.

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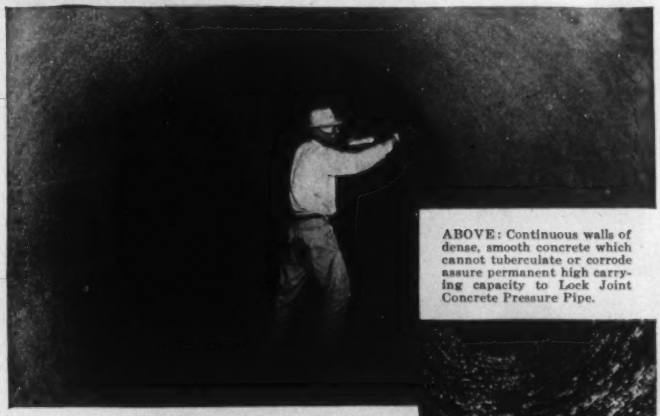

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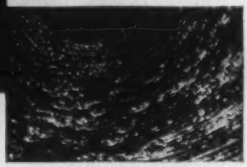

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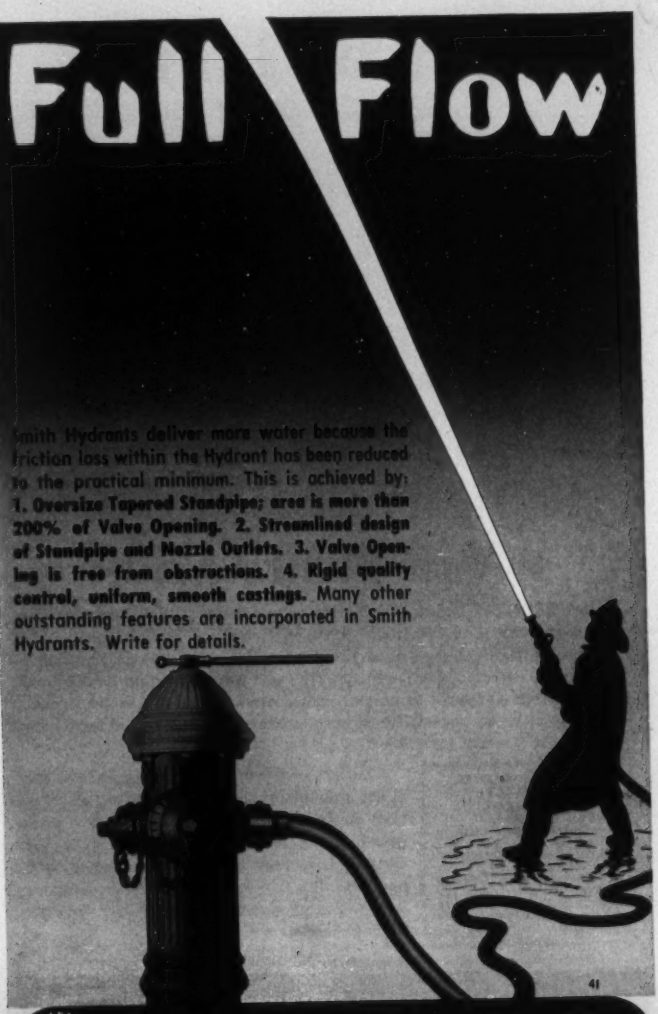

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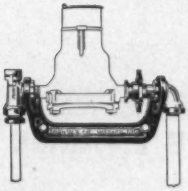

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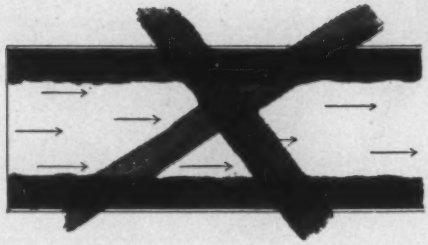

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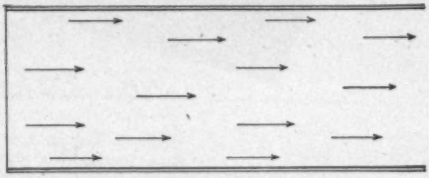

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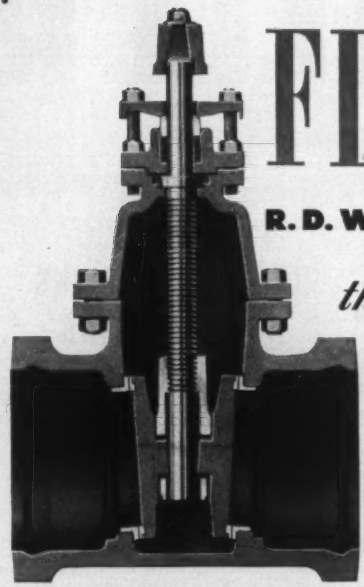

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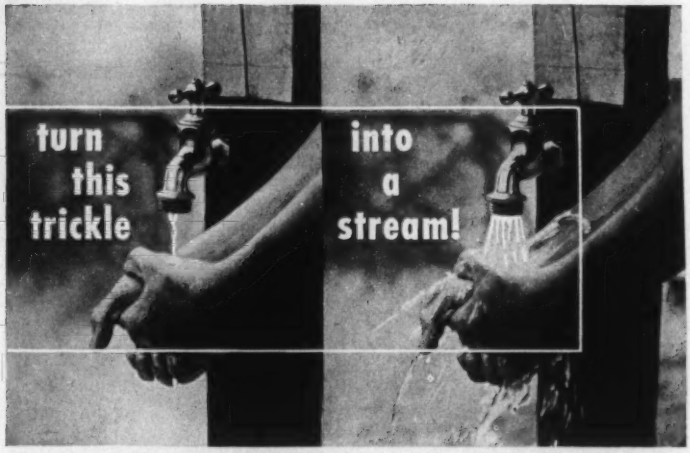

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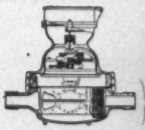

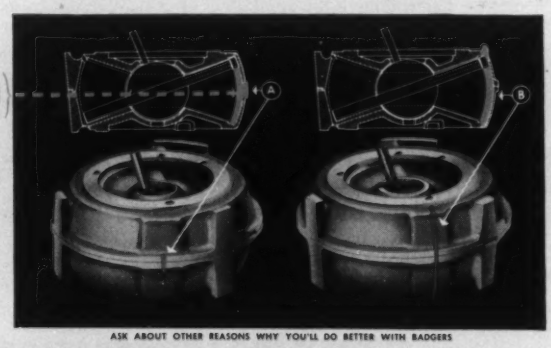

A New style: 77% shorter slot . . . adds strength to chamber-halves; prevents distortion.

B Old style: This full length slot weakened the chamber-halves . . . made them subject to distortion.

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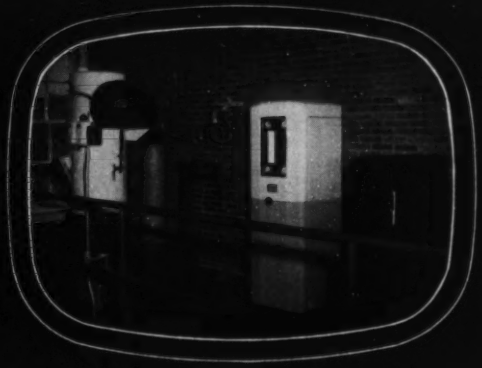

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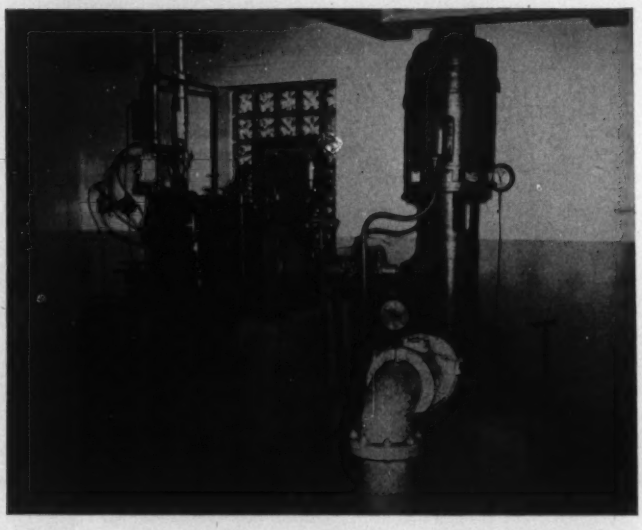

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Standard Specifications for Fire Hydrants for Ordinary Water Works Service .....Appended

New England Water Works Association
ORGANIZED 1882

VOL. LXVII SEPTEMBER, 1953 No. 3

This Association, as a body, is not responsible for the statements or opinions of any of its members

SOME ASPECTS OF THE WATER SUPPLY TO LONDON

BY H. F. CRONIN*

[*Read September 10, 1952.*]

Although from 1236 onwards conduits from various springs were laid to convey water for short distances to the inhabitants of London, it was not until the end of the sixteenth century that mechanical means were employed. In 1581 a Dutchman named Peter Morris was granted a lease of one of the arches of old London Bridge in which he erected a water wheel connected to pumps, which in turn delivered water from the river to the citizens living in the vicinity. Thirty-two years later, in 1613, Sir Hugh Myddelton, a City goldsmith, completed the construction of the New River. This is an artificial channel originally about 40 miles in length with a total fall of 18 ft. and which conveyed water from Chadwell Spring in Hertfordshire (north of London) to New River Head in Clerkenwell—the spot upon which the Metropolitan Water Board offices now stand. This channel, though shortened to 24 miles and enlarged and supplemented in flow by a connection from the River Lee and by the discharge of pumps delivering water from 11 wells, still brings water to London, although not now so far as New River Head.

The first steam engine constructed to pump water from the Thames was built about the year 1712, when Thomas Savery erected a "Savery" pump at York Building Waterworks, which occupied part of the site of the present Charing Cross Railway Station. This engine has its modern counterpart in the pulsometer pump.

While many persons continued to be satisfied with water drawn from shallow wells dug in the gravels overlying the London clay, the River Thames in the Centre and West of London and the River Lee

*Chief Engineer, Metropolitan Water Board, New River Head, Rosebery Avenue, London, E.C. 1, England.
Author's Note: (1) All quantities are in U.S. gallons, 1 Imperial gallon being taken as 1.2 U.S. gallons. (2) All tons are short tons of 2,000 lbs. (3) Costs in sterling have been converted to dollars on the basis of £1 being equivalent to 2.78 dollars.

in the East were developed for public supplies by private water companies, and by 1845 eight large companies had been established, of which five obtained their water from the tidal portion of the Thames in or near London. Of the remaining three, two, the New River and the East London Companies, derived their water from the Lee, while the source of water for the third was the River Ravensbourne, a stream flowing into the Thames at Deptford in the South East of London.

The pioneer slow sand filter bed in London was constructed in 1827 for the Chelsea Water Company by their engineer, James Simpson, and while this company subsequently filtered their water effectively, as judged by the standards of those days, it is doubtful if the same could be said for the others. In consequence of the heavy pollution of the Thames by sewage after the introduction of the water carriage system, serious complaints were made of the quality of the water supplied from this river, and in 1852 Parliament took action and compelled the Companies to move their intakes to the non-tidal portion above Teddington Weir and also to filter effectively all the water drawn from rivers.

Even though the quality of the water as supplied to the consumers improved considerably after 1852, the service given by the Companies was not satisfactory, and complaints continued to be made. These were reinforced by the failure of the East London Company to provide an adequate supply to its area during the droughts which occurred between 1895 and 1900, and in consequence of public agitation and pressure brought on the Government by the London County Council, an Act of Parliament was passed in 1902 which, by creating the Metropolitan Water Board and authorizing that body to purchase the existing Water Companies, placed the water supply of the then built-up area of London, and for a considerable distance beyond, in the hands of a public authority.

Geology, Climate and Rainfall

Before dealing with the water supply to London, some information on the geology, climate and rainfall of the country as a whole, and the East of England in particular, will enable the methods used in supplying water to the Metropolis to be better understood.

The oldest crystalline and other impermeable rocks outcrop in Wales and in the West and North of England, and the general dip is in an easterly direction. In the South-East of England and in the area from which London derives its water, the rocks belong to the mezozoic (jurassic and cretaceous) and the tertiary periods and consist of chalk and other limestones, sandstones and large areas of clay. A special feature of this area is the chalk (a soft fissured limestone) which has an outcrop of about 5,000 square miles and a thickness of over 700 feet. In addition, an appreciable area of this formation is covered by other permeable strata. The chalk is a prolific water bearing formation, and it is estimated that at least 450 m.g.d. are extracted from it for public water supplies. In addition to the chalk, some of the older limestone formations provide strong springs which maintain the flow of the rivers during long dry periods.

Within 100 miles radius of London there is practically no ground with an elevation greater than 1,000 feet above sea level, and even the area above 500 feet is limited. Most of this higher land consists of permeable formations, and in consequence large impounding reservoirs filled by gravity are not practicable in this part of England. With the exception of a few shallow stretches of water in low-lying ground, there are no natural lakes in this area.

The climate of London is temperate and there are no extremes comparable with those experienced under Continental regimes. At Kew Observatory (some 7 miles west of London) only once a year on the average does the shade temperature fall below 21° F. or rise above 85° F. and the lowest and highest values recorded are 9° F. and 94° F. respectively. The mean temperatures of the coldest and hottest months on record at Kew are 29° F. (February) and 68° F. (July and August) respectively. The coldest month is usually January, for which the average temperature at Kew is 39.5° F., while the hottest is July with a mean shade temperature of 62.8° F.

The average annual rainfall in London is 24.5 inches and the driest and wettest years on record were 1921 with 14.60 inches and 1903 with 38.10 inches respectively. The annual average rainfall (1881-1915) over the 58,343 square miles of England and Wales is 35.2 inches. It ranges from over 150 inches in the West on Snowdon in Wales and in the mountains south of Seathwaite in the Lake Dis-

trict, to less than 20 inches in the area around the Thames Estuary. The average value in the Thames Valley is 28.2 inches.

In London, during the months March to September, the standard average excess of evaporation over rainfall is approximately 2.2 inches, but during a hot and dry summer this figure may rise to over 13 inches.

Water Supply to the London Area Generally

It is not easy to determine where the sphere of influence of a large City such as London begins and ends. An area 50 miles square with London at the centre has been chosen arbitrarily to illustrate the position (Fig. 1). The population in this area is about 10 million persons, i.e. an average density of 4,000 per square mile. The water supply is in the hands of some 60 separate authorities, some being private companies and others municipal undertakings. The areas of supply of these authorities have not been determined on any logical basis, but have grown up haphazard with the general development or have followed the boundaries of local authorities. The average daily public supply to the 2,500 square miles is about 540 m.g.d., of which 370 m.g.d. is obtained from the Rivers Thames and Lee and the Stour (a river to the east of the area and not shown on the map), while the remainder, 170 m.g.d., is derived from underground sources, mostly from the chalk. In addition to the public water supplies there are a large number of private wells from which appreciable but unknown quantities—probably in the region of 120 m.g.d.—of water are abstracted.

In the centre of the map is an irregular area bounded by a thick black line. This is the area supplied by the Metropolitan Water Board and contains a resident population of about 6½ million persons and into which there is a large daily influx of office and other workers, shoppers, etc. The island inside the Metropolitan Water Board area is the Borough of Richmond, which is a separate water authority.

Metropolitan Water Board

The Metropolitan Water Board are a public body composed of 66 members elected by various local authorities within the area. They came into being in 1903, when they purchased the undertakings of the eight separate water companies which had hitherto supplied the

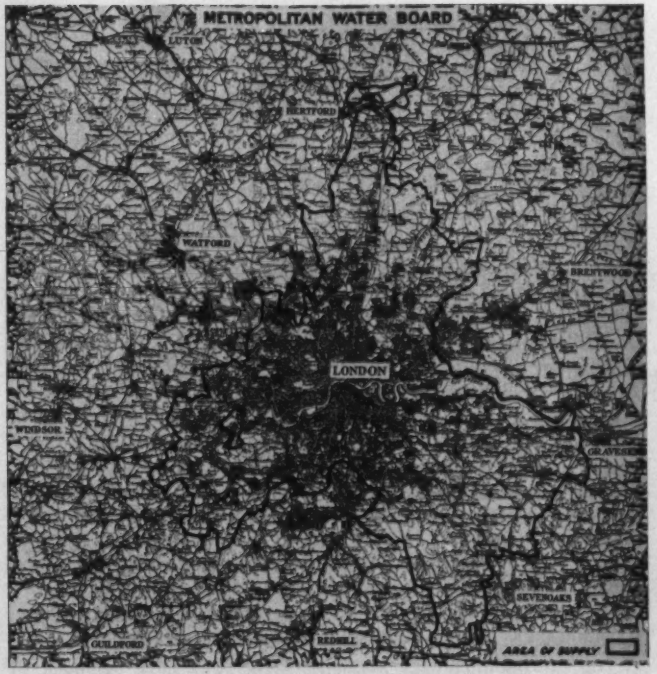


FIG. 1.—MAP OF AREA 50 MILES SQUARE WITH LONDON IN CENTRE.
(The boundary of the Metropolitan Water Board's area of supply is indicated by a thick line.)

Metropolis. They make no profit and adjust their water rate and charges from time to time so that receipts balance expenditure as nearly as may be.

The Board have no monopoly but it is unlikely that any authority which might attempt to set itself up in the Board's area of supply would obtain powers from Parliament to abstract water from any source or to break up the streets to lay pipes.

Since the method of charging has a bearing on the engineering side of the Board's activities, it should be mentioned that the Board charge for water for domestic purposes on the rateable (net annual) value of the premises supplied. The present rate is 10%. Charges for the use of a garden hose and a sprinkler are additional. For industrial purposes water is supplied through a meter, for which the average charge in 1951-52 was 14 cents per 1,000 gallons. There are about 1,344,000 domestic supplies and 31,000 supplies through meters.

No charge is made for the use of water for the extinction of fires by the Fire Brigades, and the Board are under no obligation to maintain any specific pressure in their mains for this purpose.

The Board's expenditure on revenue account (i.e. excluding capital) for the year 1951-52 was approximately 25,400,000 dollars, i.e. the cost in dollars per million gallons supplied was 180. Of this amount, the engineering operations and the examination of water cost about 10,670,000 dollars or 42% of the total as set out below:

	Dollars
Abstraction, protection and storage	955,000
Filtration	810,000
Special treatment of water	210,000
Pumping and engine charges	4,500,000
Distribution	3,220,000
Salaries, Engineer's Department (where not included in above)	835,000
Examination of water	140,000
	10,670,000

Of the remaining 14,730,000 dollars no less than 11,400,000 dollars or 45% of the total was expended upon local rates, payment of interest and redemption of debt charges.

Consumption of Water

Fortunately the consumption of water per head is not so high in Britain as in the United States. Some representative figures of the supply for all purposes are:

Glasgow	80 g.h.d.
Manchester	60 "
Metropolitan Water Board	58 "
Birmingham	44 "

The total average daily supply by the Board in 1951-52 was 386 m.g.d. Of this, 7 m.g.d. was supplied in bulk to other authorities and 125 m.g.d. supplied by meter to industrial consumers. The balance of 254 m.g.d. was supplied for domestic purposes, and this figure includes all losses by leakage and waste (except those on the consumers' side of the meters).

The total average daily supply (excluding bulk supplies) has risen from 252 m.g.d. in 1903-04 to 379 m.g.d. in 1951-52, while the population supplied, which was over 7,000,000 just prior to the second war, has remained substantially the same, being 6,400,000 in 1904 as against 6,500,000 today. The rise in consumption has been irregular and has been influenced by the two wars, the weather, the effect of restrictions in drought years, as well as by propaganda. Separate figures for the supply of water by meter for industrial purposes have only been recorded since 1911 (Fig. 2), but during that period the metered supply has risen from 67 to 125 m.g.d., i.e. it has nearly doubled, while the unmetered supply has only risen from 224 to 254 m.g.d., an increase of a little over 13%.

These figures are somewhat perplexing considering that a very large number of new houses, all equipped with baths and hot water heating apparatus, and many with gardens, have been constructed since 1911, and the general tendency has been for more and more people to live in the Suburbs in modern houses and to vacate the older premises in the centre of London, making this area available for business and trade purposes.

It is not easy to offer explanation for the vagaries of the statistics representing domestic consumption since these are obtained by deduction and include leakage and waste. It is, however, quite probable that some of the methods adopted for measuring the total supply delivered from the works were (and in some cases still are) not wholly accurate and that the effects of the efforts to detect and stop waste and leakage, together with an improvement in the standard of water fittings, have exercised an influence upon this figure.

Waste Detection

On account of the relative shortage of water, the expensive nature of new works, the cost of pumping and the method of charging for

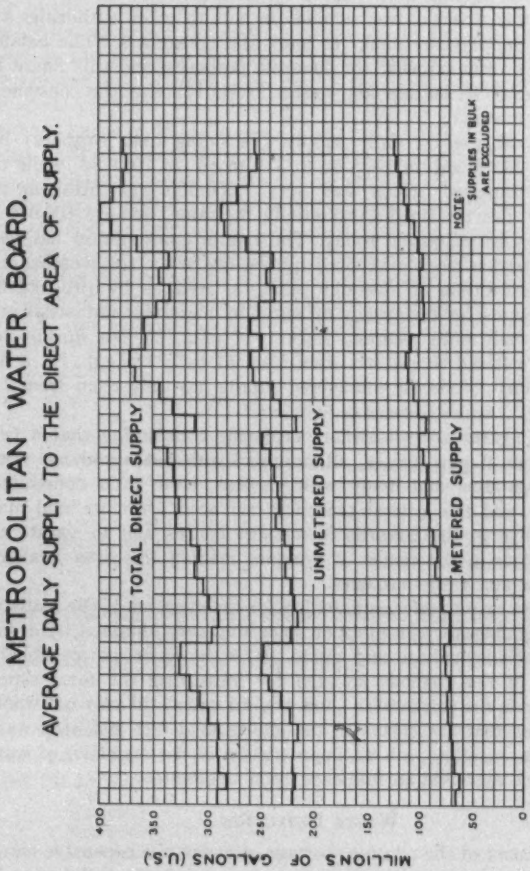

METROPOLITAN WATER BOARD.
AVERAGE DAILY SUPPLY TO THE DIRECT AREA OF SUPPLY.
TOTAL DIRECT SUPPLY
UNMETERED SUPPLY
METERED SUPPLY
NOTE: SUPPLIES IN BULK ARE EXCLUDED
MILLIONS OF GALLONS (U.S.)
400
350
300
250
200
150
100
50
0
1911-12
1912-13
1913-14
1914-15
1915-16
1916-17
1917-18
1918-19
1919-20
1920-21
1921-22
1922-23
1923-24
1924-25
1925-26
1926-27
1927-28
1928-29
1929-30
1930-31
1931-32
1932-33
1933-34
1934-35
1935-36
1936-37
1937-38
1938-39
1939-40
1940-41
1941-42
1942-43
1943-44
1944-45
1945-46
1946-47
1947-48
1948-49
1949-50
1950-51
1951-52
1952-53
1953-54
1954-55
1955-56
1956-57
1957-58
1958-59
1959-60

FIG. 2.

domestic supplies (which provides the consumer with no incentive to economize), the Board, in common with many other water undertakings in Britain, take special precautions to detect and prevent waste and to discover leakage from pipes in the ground, this latter being the greatest source of loss. In the Board's distribution system nearly all the service (4" and 6") pipes are so arranged that they can be divided into isolated areas and the flow into these recorded by waste water meters fixed on by-passes (Fig. 3). The consumption in each of the "waste meter districts" (which now number over 3,000) is measured, as a matter of routine, during the night once in every eight weeks, and if the minimum flow has increased, a search is at once made to discover the cause. This is done by isolating the area covered by the meter and then shutting down, in rotation and at pre-determined times, the valves controlling the various streets or lengths of main, and the extent to which water is being used or wasted is indicated by the vertical drop in the line on the diagram when each valve is shut off. Thus the location of the leakage can be determined within narrow limits and, by sounding with stethoscopes or by the use of electrical devices, the exact position of the leakage is soon detected.

The Board spend annually about 230,000 dollars in salaries and wages on waste detection, this being about 4% of the total salary and wages bill of the Engineer's Department. Very satisfactory results have been obtained from the efforts made in this direction, especially since the end of the war, and about 200,000 defects on consumers' apparatus and the Board's mains are discovered annually.

There has been a reduction in consumption of nearly 25 m.g.d. between 1947 and 1951, and this is largely attributable to intensive waste detection methods. Due to increased trade requirements, the replacement of old houses by modern buildings with adequate water using facilities, etc., the consumption is now rising slightly.

The Board have power to make, and have made, Byelaws enforceable by law for the purpose of preventing the waste, undue consumption, misuse, or contamination of water. Under these Byelaws fittings, etc., installed or to be installed in premises can be required to conform to certain requirements and the use of fittings likely to cause waste prohibited.

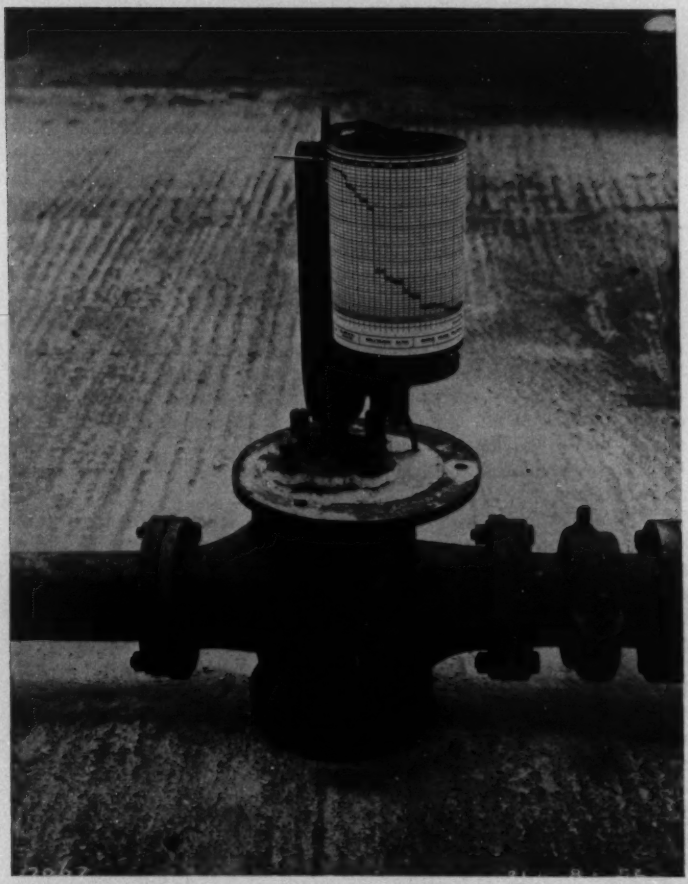


FIG. 3.—WASTE WATER METER.
The chart shows the reduction of the night flow by the successive closing of valves in the area governed by the meter. Note the large reduction in flow denoted by the vertical line towards the centre of the diagram, indicating leakage or excessive use of water in one area or street.

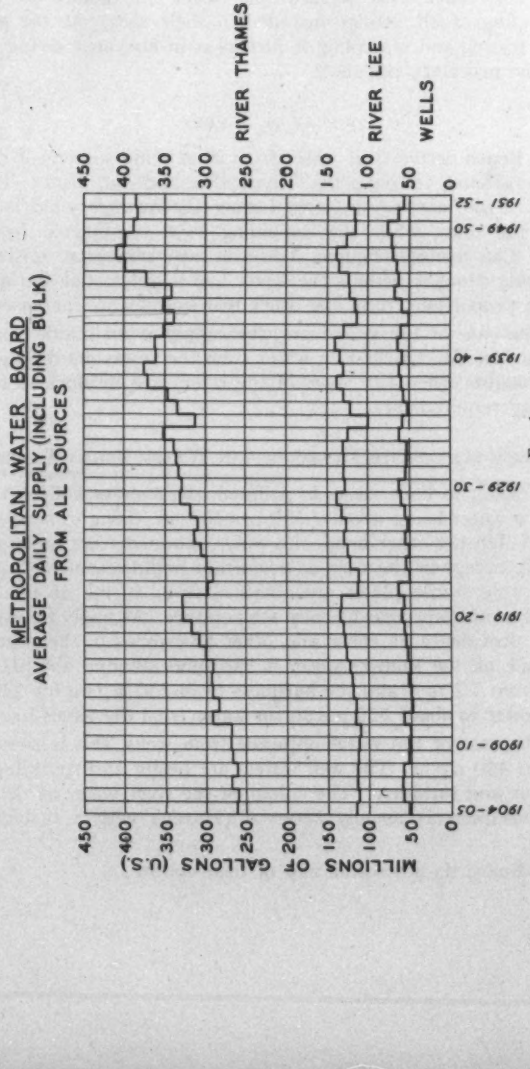

METROPOLITAN WATER BOARD
AVERAGE DAILY SUPPLY (INCLUDING BULK)
FROM ALL SOURCES
MILLIONS OF GALLONS (U.S.)
450
400
350
300
250
200
150
100
50
0
RIVER THAMES
RIVER LEE
WELLS
1904-05
1909-10
1919-20
1929-30
1939-40
1949-50
1951-52

FIG. 4.

Further, under these Byelaws the Board can require the testing and stamping of all fittings installed in their area. At the present time the testing and stamping of fittings is in abeyance owing to the lack of the necessary premises.

Sources of Supply

The Board derive their water from three main sources of supply, viz. underground sources, the River Lee and the River Thames (Fig. 4). From each of the two former the average yield is about 16% of the total, while the remaining 68% is obtained from the Thames. The average figures, however, are somewhat misleading, since during drought periods the River Lee is apt to fail and at such times the proportions from the other two sources are increased.

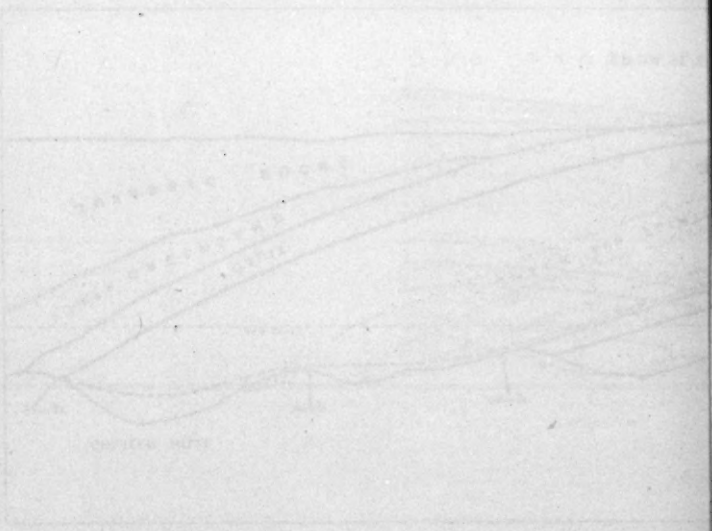
In the case of the two rivers, the supply is maintained by continuous abstraction assisted by water from the reservoirs during occasional droughts when the flows in the rivers are insufficient for the day to day requirements.

Character of the Metropolitan Water Board Water

The water in both rivers is polluted, the average coliform count of the raw water being about 2,500 per 100 ml. rising to a maximum of 60,000. On the other hand, the water obtained from underground sources is, except in the case of accidental pollution, of high purity, and as a rule sterile plates are obtained from 10 ml. of this water incubated in nutrient agar at body temperature. As might be expected from the prevalence of chalk and other limestones in the south-east of England, all the Board's water is hard and alkaline, the pH value varying from 7.2 to 8 and the hardness from 250 p.p.m. for Thames-derived water to about 350 p.p.m. for water from the River Lee.

In the case of the water obtained from wells, this is sometimes as hard as 400 p.p.m. The well waters are bright and sparkling with zero colour and turbidity. The colour of the river water as delivered to the consumers is usually about 6 (Hazen) with a turbidity of 0.2 p.p.m.

The Board do not soften any of their supply.



METROPOLITAN V

SECTION ACROSS THE LONDON

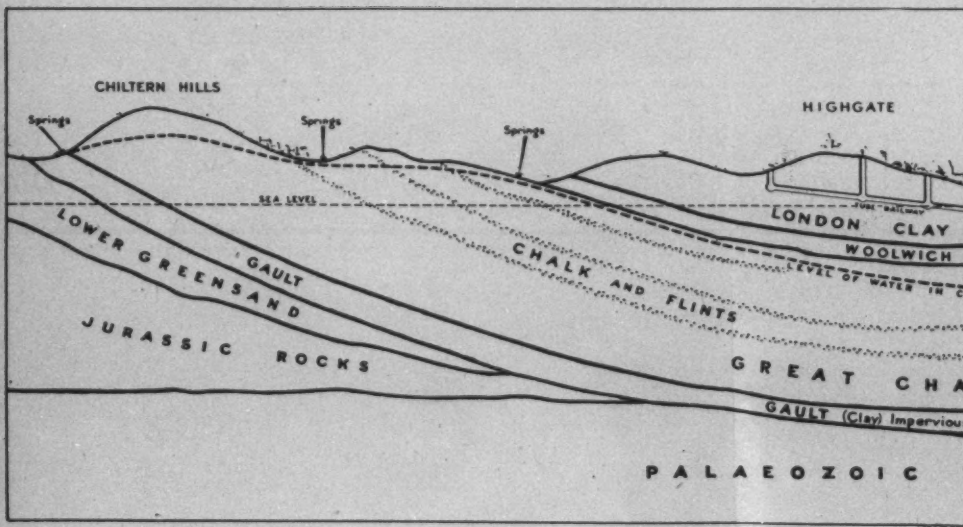
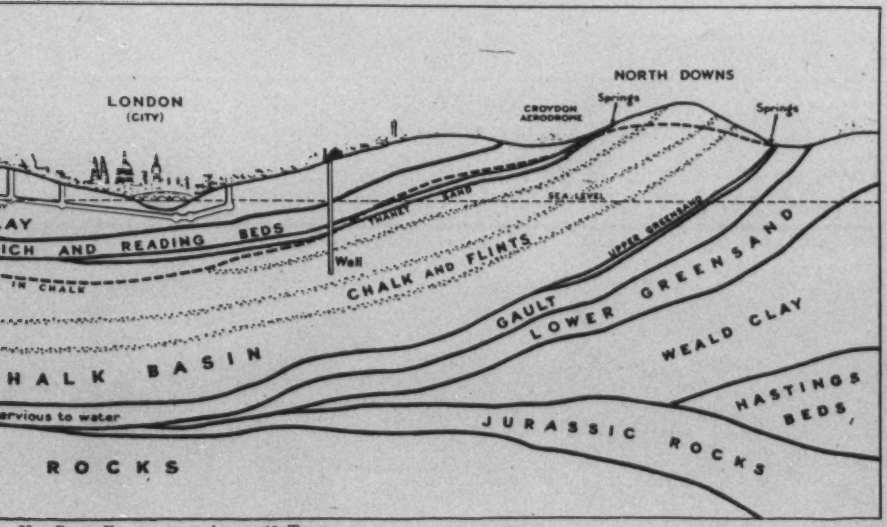


FIG. 5.—NOTE — THE VERTICAL SCALE HAS

WATER BOARD

ON BASIN FROM N.W. TO S.E.



E HAS BEEN EXAGGERATED ABOUT 40 TIMES.

METROPOLITAN W

SECTION ACROSS THE LONDON

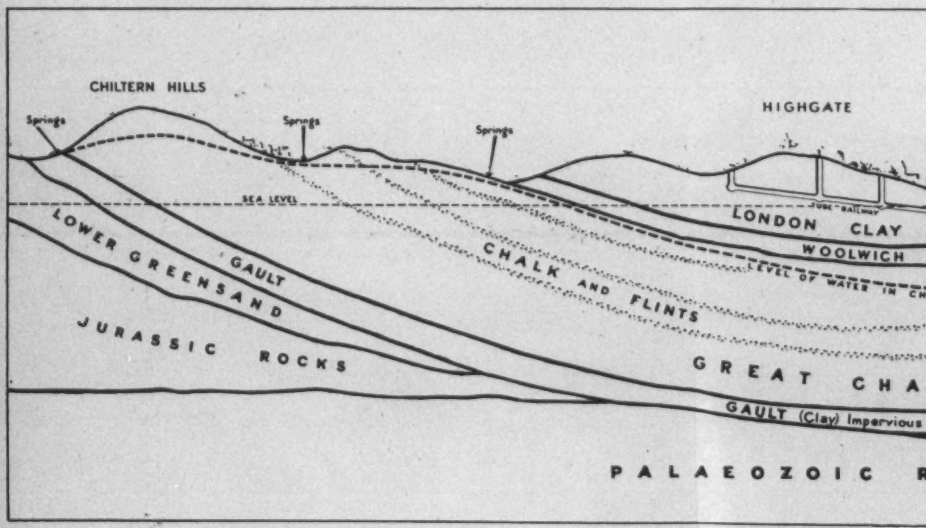
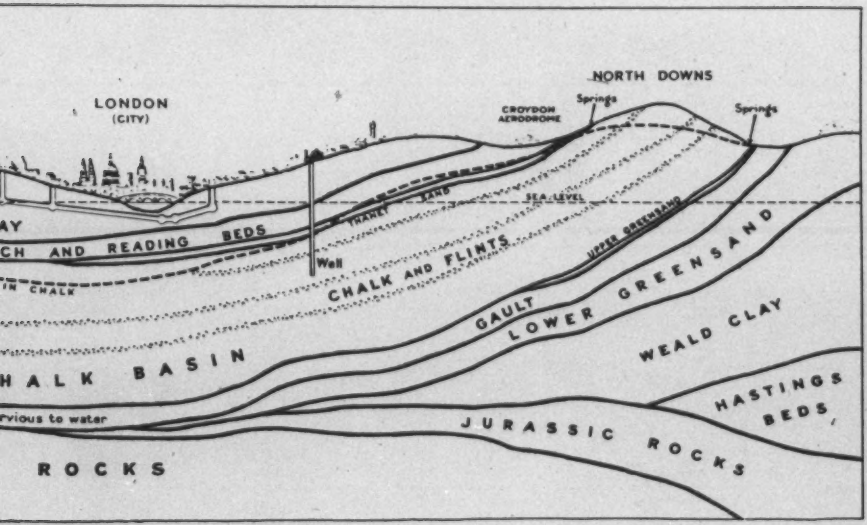


FIG. 5.—NOTE — THE VERTICAL SCALE HAS

WATER BOARD

ON BASIN FROM N.W. TO S.E.



E HAS BEEN EXAGGERATED ABOUT 40 TIMES.

Underground Sources

The geological structure in the vicinity of London is exceptionally favourable for the supply of underground water, as the area is situated in an artesian basin or trough formed by a thick layer of chalk which outcrops over a large area within a distance of 10 to 30 miles north and south of the city, and which is sandwiched between two layers of clay (Fig. 5). A hundred years ago the basin was truly artesian, i.e. water would have overflowed in the centre of London if the clay were pierced by a boring to the chalk, but owing to overpumping, mostly from privately owned wells, the water level has sunk so much that in places it is 250 feet below Ordnance Datum (i.e. mean sea level).

Prior to the second war the water level under the City of London was falling at a rate of over 3 feet per annum. During the war the pumping from privately owned wells was greatly reduced and many of the premises at which these were situated were destroyed, as a result of which the water level rose. No precise data for this area is now available but the water level is again falling, though not so rapidly as in 1939. On the other hand, there are some areas in London where the level is now rising slightly, possibly due to some of the underground supplies being put out of use as a result of destruction by bombing and to the effects of legislation, to which reference is made later.

The Board's wells, of which there are 57 in which pumps are installed at some 40 separate works, are mostly situated near to, or on, the outcrop of the chalk and are in general outside the overpumped area. The yields of individual stations vary from about 0.5 m.g.d. or less to over 6 m.g.d., and the total reliable yield from this source in a drought year is about 78 m.g.d.

Owing to the spread of urbanisation many well sites which were in open country only a few years ago are now surrounded by built up and sewered areas. Frequently the chalk has no protective covering of clay and if any of the sewers become defective, pollution may easily find its way through the fissures in the chalk to the underground water and so almost instantaneously into the wells. This has already occurred on more than one occasion and special measures, such as

the employment by the Board of a Drainage Inspector and an Assistant, are exercised to protect the underground water.

On account of this danger all the well water is chlorinated and allowed twenty minutes' contact before being pumped into supply. The dose of chlorine varies from 0.5 to 1 p.p.m. (although 0.1 p.p.m. would be sufficient to destroy any coliform bacteria) and dechlorination is effected by sulphur dioxide after a minimum contact time of twenty minutes.

Another cause of pollution of the chalk water is the ingress of estuarine water from the river. About 20 miles downstream of London Bridge the chalk outcrops in the bed of the river and in former years springs flowed from the chalk into the Thames. In consequence of overpumping the level of the ground water has been so lowered that the flow is reversed and water from the river is now finding its way back into the chalk with a consequent rise in the chloride content of water pumped from nearby wells.

During the last few years legislation has been enacted to prohibit, in London and elsewhere, the sinking of new wells, or the increase of abstraction from existing wells, except under a license issued by the Ministry of Housing and Local Government. By this means it is hoped to control the indiscriminate abstraction of underground water which has already seriously damaged the yield of many wells in the London basin. Wells used solely for domestic purposes for the supply of a household do not come within these provisions.

The use of deep well water for public water supplies in London dates from about 1830.

The River Lee

For over 200 years water from this river has been supplied to the East of London, North of the Thames. This is a most important area as it contains nearly all the Docks, as well as numerous factories, together with a large resident population employed in these industries.

The Lee is a small river, with a total length of 56 miles from its source to the point where it joins the Thames. It has been gauged since 1886 at a point known as Feilde's Weir, which is below the confluence of the lowest important tributary and some 24 miles upstream of its mouth. The catchment area above the gauging weir is 414 square miles and over this the standard average rainfall is 25.65

inches per annum. The average daily natural flow (i.e. the flow as it would be if there were no abstraction) is 132 m.g.d., but during a dry summer this has fallen as low as 19 m.g.d. during two consecutive months.

Reservoirs to contain about 9,600 m.g. have been constructed from time to time in the valley of this river but owing to the low flows which are experienced in the winter, it is not always safe completely to empty the reservoirs in any summer in case they cannot be replenished during the following winter.

For many years developments have been taking place in the valley of the Lee, including the erection of large numbers of new houses and factories and a great number of glasshouses, resulting in more and more water being abstracted from public and private wells to meet the increased demands. In consequence many of the springs feeding the river have dried up and the flows during dry periods are becoming less and less.

A further disadvantage is that increasing quantities of sewage effluent are being turned into the river. These are undesirable in themselves and, in addition, make the water more difficult to purify, especially as nearly half the water abstracted from the Lee passes down the New River, which is not connected to storage reservoirs and, therefore, such water is deprived of the beneficial effects of storage.

In addition, complaints of taste of the water from this source are by no means infrequent and their cause is extremely difficult to trace.

From the foregoing it will be evident that the Lee is a most unsatisfactory source of supply and it is not improbable that at some future date it may have to be abandoned altogether. This contingency has been recognized and the Board have approved the laying of a 75″ main across London through which raw Thames water will be pumped to the Lee Valley storage reservoirs. The decision to transfer unfiltered instead of filtered water was taken because by this means it will still be possible to make use of the storage reservoirs, filtration works and the distribution network connected to the pumping stations in the Lee Valley. If filtered water were supplied it would be necessary to construct additional storage reservoirs and filtration plant in the Thames Valley and either to re-arrange the distribution system in East London or incur the heavy cost of making numerous

connections in streets which are already congested with pipes and other apparatus. Further reference to the 75" raw water main is made later in this Paper.

At the present time the safe yield of the Lee and its reservoirs during a dry summer is not greater than 53 m.g.d. This cannot be increased as there are no more sites for reservoirs in the Lee Valley, and indeed it would not be economical to construct any further storage in this valley as the river is already "over-reservoired".

The historic New River obtained its water in the first instance from Chadwell Spring in Hertfordshire. Later, when the spring proved insufficient, a cut was made from the adjacent channel of the River Lee. Now, due to overpumping, the spring nearly always fails in the summer, but the flow down the channel of the New River is maintained by water from the Lee and by pumping from 11 wells situated along its course.

The Board have the right to abstract the whole of the flow of the Lee with the exception of 6.5 m.g.d. which is reserved for navigational purposes.

The River Thames

This river has been the main source of water supply to London for centuries. It is still the most important source and the only one which can be expanded. In addition the river is used extensively for recreational purposes and its amenities are jealously guarded.

The Thames rises in the Cotswold Hills at an elevation of between 360 and 370 feet above sea level, about 90 miles west of the centre of London, the distance measured along its course to London Bridge being 143 miles.

The river is fed by numerous tributaries and springs from the jurassic and cretaceous formations and, owing to the ability of these rocks as well as of the gravel beds which occur all along the river valley to store large quantities of rain water, the flow is well maintained during periods of dry weather.

Although the water is polluted and nearly 2,000,000 persons reside in the catchment area above the Board's intakes, there are, fortunately, no large manufacturing centres in the valley of the river and in consequence, with adequate treatment, the water is suitable for water supply purposes.

The flow of the river is gauged at Teddington Weir (19 miles upstream of London Bridge). This Weir marks the highest point to which the tide rises and the catchment area above it is 3,855 square miles, over which the standard average rainfall for the 35 years, 1881-1915, was 28.21 inches per annum. The percentage run-off varies from 20 to 46. Systematic gaugings of the flow have been taken for nearly 70 years, and thus there is ample data upon which to base calculations of the yield of the river and the capacity of the requisite storage reservoirs.

For the period 1883 to 1917, which is taken as the standard for averages, the natural flow (i.e. the flow of the river as it would be if there were no abstraction) at Teddington Weir was 1,628 m.g.d. The highest recorded natural flow on any one day was 24,283 m.g. on the 18th November, 1894, and the lowest, 169 m.g. on the 9th July, 1934.

There have been five years during which the summer flows have been unduly low and particulars of these are set out, together with the standard average figures, in the following table:

AVERAGE DAILY NATURAL FLOW OF RIVER THAMES IN DROUGHT YEARS IN M.G.D.

Month	Standard Average	1899	1921	1934	1944	1949
May	1,315	800	578	533	415	754
June	983	445	394	331	308	524
July	715	360	246	289	322	330
August	659	277	274	301	257	288
September	633	329	336	318	347	301
October	1,080	461	347	345	665	1,174
November	1,783	1,248	406	494	2,289	2,117

The relative severity of these droughts measured by the amount of storage required to cope with each and denoting 1921 by unity is:

1921	1.00
1934	0.99
1944	0.91
1949	0.69
1899	0.69

A comparison of the natural flows during the summer and autumn months of 1921 and the standard average flows is shown in Fig. 6.

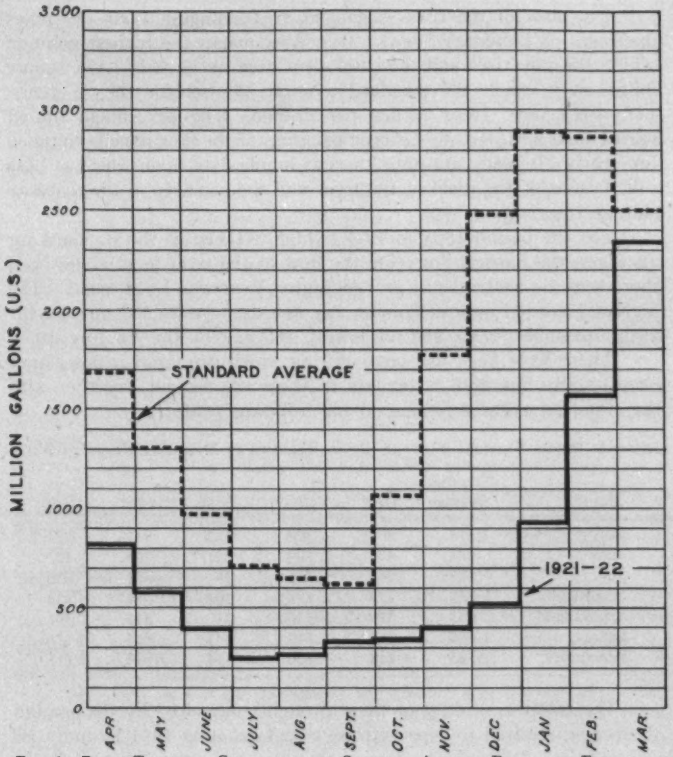


FIG. 6.—RIVER THAMES — COMPARISON OF STANDARD AVERAGE FLOW AND FLOW IN A DROUGHT YEAR.

The amount of water which the Board are allowed to abstract is governed by Act of Parliament, the most important condition being that the flow over Teddington Weir must not be reduced by abstraction by the Board below 204 m.g.d. As the permitted abstraction is insufficient during dry years, the deficiency has to be made up by

drawing water from storage reservoirs. If, for any reason, the amount of water in store is inadequate, provision has been made in the Act of Parliament, governing the abstraction, for the reduction of the flow over Teddington Weir to be made in an emergency by a joint Order from the Ministries of Transport and Housing and Local Government. As will be seen, the Board do not, at present, possess sufficient storage to tide them over a period of drought, and whenever there is a severe drought, the powers for making this Order have to be invoked.

The average daily abstraction over a year must not exceed 360 m.g. (but this will be increased when more reservoirs have been constructed) and the maximum amount which may be taken from the river on any one day is 1,440 m.g.

Yield of River Thames

The yield of the Thames over a period of drought is comprised of the quantity of water which can be legally abstracted from the river plus the amount available from the storage reservoirs. To provide a basis for the calculation of the capacity of these, the Board have decided to frame their storage policy on the assumption that the flows of the drought year of 1944 will be repeated and, if a more severe drought, such as that of the type of 1921 or 1934, is encountered, to make use of the provisions allowing for the increase of abstraction at the expense of the flow over Teddington Weir.

The records of the natural flow of the river for each day during 1944 are available and it is, therefore, only a matter of arithmetic to ascertain the amount of storage required to provide a given supply after making allowances for the abstraction of water by neighbouring Water Companies, the maintenance of the statutory flow over Teddington Weir, and providing a 15% margin for contingencies. If it is accepted that the Lee and the wells together will yield 131 m.g.d., the relation between the total average daily supply and the storage required in the Thames Valley can be plotted and the diagram (Fig. 7) shows the relation between these two quantities.

At the present time, the Board have storage reservoirs containing 21,240 m.g., but all of this is not readily available. For the 1951-52 average daily demand of 386 m.g., the Thames storage required, on

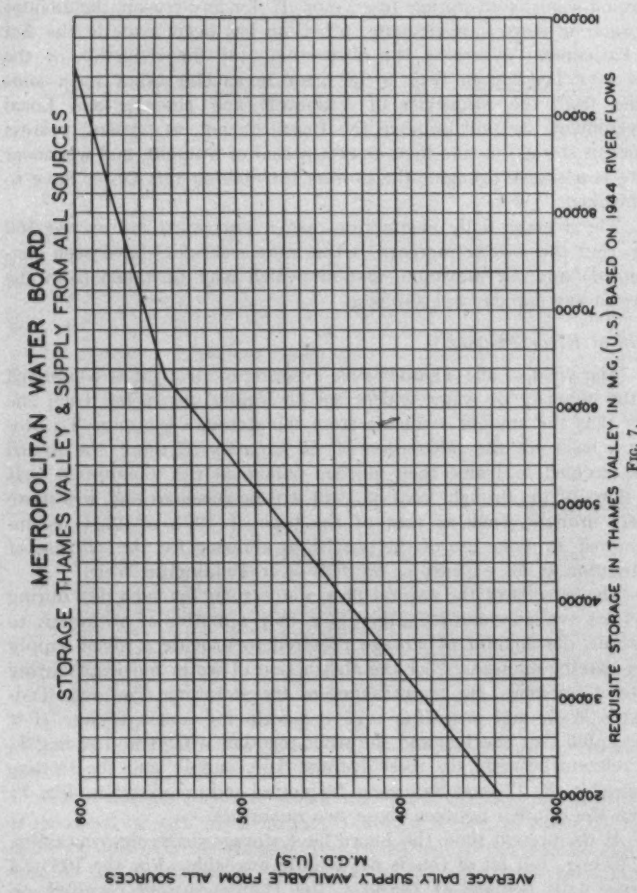

METROPOLITAN WATER BOARD
STORAGE THAMES VALLEY & SUPPLY FROM ALL SOURCES
AVERAGE DAILY SUPPLY AVAILABLE FROM ALL SOURCES
M.G.D. (U.S.)
600
500
400
300
REQUISITE STORAGE IN THAMES VALLEY IN M.G. (U.S.) BASED ON 1944 RIVER FLOWS
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000

FIG. 7.

1944 flows, would be 30,000 m.g., so the deficiency is now about 8,800 m.g.

With the experience which is available of the gauging of the Thames over so many years, a summer in which low flows may be expected can be forecast by observing the winter rainfall and the flows, and preparations made in due time for the maintenance of the supply by the issue of propaganda, applying for an Order to reduce the flow over Teddington Weir, and prohibiting the watering of gardens. The unknown factor in the calculation is, of course, the date upon which the drought will end and, in consequence, it is always necessary to use the storage somewhat sparingly even though this involves reducing the flow over Teddington Weir to a greater extent than would appear necessary when the drought is over.

Ultimate Yield of River Thames

The total amount of storage which it is economical to provide is governed by the amount of water available for re-filling in a dry winter following upon a dry summer. The most difficult period on record occurred during the years 1943-44 when there was a hot dry summer (1943) with moderate river flows, followed by a dry winter with poor winter flows. The summer of 1944 was again hot and dry with very low flows. After that, there were for some years adequate and copious river flows. It can easily be shown that, if such a period recurred and if the Board possessed a storage capacity of 63,000 m.g., and were at the same time providing a total average daily supply of 545 m.g. (this being the supply appropriate to a Thames storage of 63,000 m.g.), it would have just been possible to replenish the reservoirs during the winter of 1943-44, and by the end of the summer of 1944 they would have been empty (except for the 15% margin for contingencies). If a greater amount of storage were available and the total supply increased above 545 m.g.d., the whole of the depletion could not have been made good during the dry winter and, in consequence, some of the storage would have been required to last over two summers and an intervening winter. Put in other words, the investigations reveal that, up to a supply of 545 m.g.d. from all sources, the amount of storage required would be about 200 m.g. for every million gallons supplied. If, however, the supply is increased

beyond this, the amount would be 590 m.g. or nearly three times as much. This is shown clearly by the change of slope in the line in Fig. 7.

Construction of Storage Reservoirs

It has already been observed that there are no valleys near London which can be dammed up to form impounding reservoirs. In consequence, a pond type of reservoir containing from 1,000 m.g. to 8,000 m.g., constructed on flat ground and with continuous artificial banks, has been evolved (Fig. 8).

The strata to the West of London and in parts of the Lee Valley has lent itself to this type of reservoir, for in many places the solid London clay is only 20 or 30 feet below the surface and is covered with a layer of sand and gravel which forms an excellent foundation as well as providing suitable material for the bank. This latter is rendered watertight by a core wall of puddled clay carried down and tied into the underlying London clay. The Board have all the necessary powers and own the land for three more reservoirs to contain together about 16,000 m.g., which will increase the available supply by about 78 m.g.d, but on account of the restriction on capital expenditure by the Government, they have not been allowed to proceed with the construction of any of them. Once these reservoirs are built, great difficulty will be experienced in finding other sites near London. Almost immediately to the West of the present area in which reservoirs have been built, the London clay ceases to exist and is replaced by the pervious chalk. If sites still further to the West again are selected, expensive conduits will be involved.

It has been suggested that the channel of the river might be used to convey water from reservoirs situated in the higher reaches, where a clay bottom could be found, to the existing intakes in the vicinity of London. The first reactions of the River Authority to this proposal were unfavourable on account of the algal water which would be discharged from the reservoirs and which was alleged to have a very high B.O.D. The matter, however, requires further investigation since the cost of the conduits may be of the order of half a million dollars per mile and their routes, either through the built-up and waterlogged areas adjacent to the devious channel of the river, or in a straight line through masses of water-bearing chalk from which many

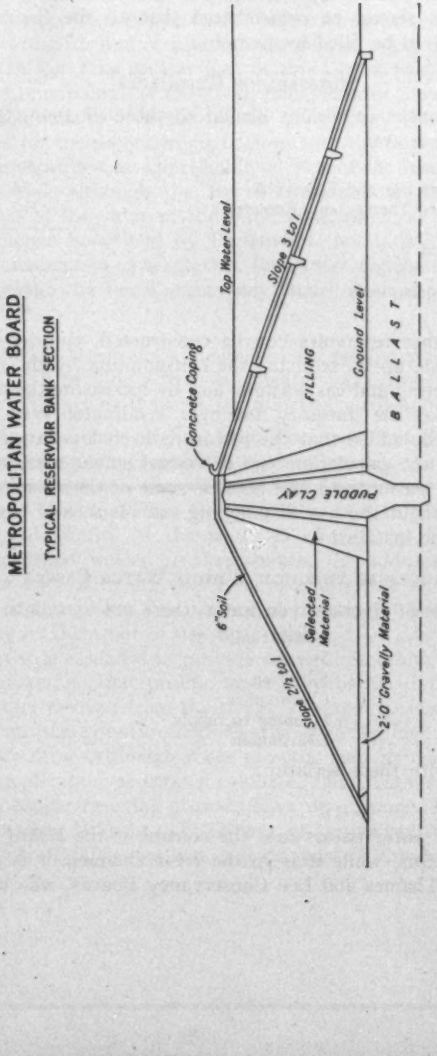

METROPOLITAN WATER BOARD
TYPICAL RESERVOIR BANK SECTION
Top Water Level
Slope 3 to 1
Concrete Coping
FILLING
Ground Level
BALLAST
PUDDLE CLAY
6"Soil
Selected Material
Slope 2½ to 1
2'0"Gravelly Material
LONDON CLAY

FIG. 8.

Authorities draw their supplies, would be a matter of some difficulty.

Finally, it should be remembered that all the Board's storage reservoirs have to be filled by pumping.

Summary of Resources

Under drought conditions similar to those of 1944, the Board's present resources are:

From Wells	78 m.g.d.
From River Lee and Reservoirs	53 "
From River Thames and Reservoirs	210 "
Total	341 m.g.d.
Present requirements	386 m.g.d.
Deficiency	45 m.g.d.

Until further reservoirs can be constructed, the deficiency will have to be made up by reducing the consumption by the prohibition of garden watering and car washing and by increasing the abstraction at the expense of the statutory flow over Teddington Weir.

It should be added that the picture is even less favourable than depicted, since the calculations are not based on the most severe type of drought yet encountered and because some of the reservoirs cannot be emptied without the use of pumping out plant, and much of this has not yet been installed.

Processes through Which Water Passes

In the case of river-derived water, these are as follows:

Abstraction
Storage
Filtration
Chlorination
Pumping to supply
Distribution

Dealing with these seriatim:

Abstraction

The river water passes into the control of the Board at the intakes. Before this, while it is in the river channels it is under the control of the Thames and Lee Conservancy Boards, who have juris-

diction over these rivers and possess wide powers to prevent pollution.

The Metropolitan Water Board have representatives on both the Conservancy Boards and make a contribution of approximately 90,000 dollars to the Lee (the greater part of this is now paid to the British Transport Commission, as that body has recently assumed responsibility for the canalised portion of the river) and 486,000 dollars to the Thames for their work in connection with the protection of water. These sums represent an appreciable portion of the income of the two authorities and, although the Board consider that these payments are in excess of the value of the work undertaken on their behalf, it has nevertheless been held by Parliament that it is in the interests of the community in general that the water consumers of London should subsidise the two Conservancy Boards.

Storage

The storage reservoirs are required for two purposes:

(1) To provide a reserve of water for a drought period.
(2) To act as the first stage in the purification process.

The first use has already been discussed and the second was brought into prominence about 50 years ago by the researches of Sir Alexander Houston who was the first Director of Water Examination of the Board. Suffice to say that a great improvement in the bacteriological quality of the water is effected by its retention in storage for three weeks or thereabouts. In addition, sedimention takes place and, although this is appreciable, the silting up of the reservoirs is a very slow process, and it has not yet become necessary to take any of them out of use for cleaning.

Whilst it is essential to provide storage reservoirs, they have the great disadvantage that prolific algal growths occur in them as the alkaline water derived from the rivers is extremely favourable to this development, the count sometimes rising to as high as 50 million colonies per litre. Although these growths may be controlled by the judicious application of copper sulphate, this treatment is used with caution as copper-resisting growths have on occasions been produced. During the year 1951-52 only 40 tons of copper sulphate were used, whereas over 100,000 million gallons passed through the storage reservoirs.

Up to the present, the Board have no experience of the effects of thermal stratification on the prolonged storage of Thames- or Lee-derived waters in reservoirs greater than about 40 feet in depth. A new reservoir of 52 feet in depth has recently been brought into use, but it is too early to say whether or not troubles will arise in it due to the deoxidation of the lower layers of the water by the decomposition of algal growths falling down from above. On a few occasions, however, the bottom water withdrawn from some of the older and shallower reservoirs has been found unsuitable for use in the existing filtration plant. On account of the extreme shortage of reservoir sites, it is essential to construct further reservoirs to the greatest depths which engineering considerations will permit, but, if this results in a large volume of unusable water lying in the bottom of the reservoir in the summer, part of the object of providing additional storage will be defeated.

Research work is now proceeding actively on this subject, but what is needed is practical experience of the behaviour of water of the type with which the Board have to deal in reservoirs over 50 feet in depth. If time permits, the best method would appear to be to proceed by stages, building each new reservoir a little deeper than the one before it.

At the present time the cost of storage reservoirs (without conduits to convey the water to the filtration plants) is about 2,500 dollars per m.g. stored.

The annual cost of operating, upkeep, etc. of the storage reservoirs is about 375,000 dollars or 1.5% of the total expenses of the Board.

Filtration

The Board's standard practice for the purification of the river-derived supplies is to rely upon slow sand filtration and terminal chlorination. To speed up the passage of the water through the slow sand beds the water is first passed through rapid sand filters operating without a coagulant. Although the ammonia is oxidised and some bacterial improvement is effected during the passage of the water through the rapid filters, their function is to reduce the algal load on the slow sand beds. A photograph of a dual filtration plant is shown

in Fig. 9. The rate of filtration is approximately 240" per hour through the rapid filters and 8" per hour through the slow sand beds. It should be added that not all the works have yet been equipped with dual plant but about 63% of the water filtered is dealt with in this manner.

The slow sand beds differ very little from those introduced by Simpson in about 1829. The reason why the Board continue to use this type of filter is that it has not been possible, in spite of experiments in the laboratory and on a full scale, to discover a satisfactory method of coagulating the algal waters, containing but little silt, which are derived from the reservoirs. The river water can be coagulated, but, since it is essential to have a plant which can deal with the stored waters, it has been impracticable to adopt this method of purification.

At the moment the Board have 74,544 sq. ft. of rapid filters, 161 slow sand beds measuring 159.7 acres, and are building 24.7 acres (32 beds) of the latter. This new work is not only required to augment the supply but to replace two other smaller works where some of the filter beds are nearly 100 years old and where the plant generally is not in good condition.

The rapid filters are cleaned as a matter of routine every 24 hours but during periods of heavy algal growths the run may be as short as 3 or 4 hours. The slow sand filters often run for as long as 8 weeks but their minimum runs are as low as 6 to 10 days. The rapid filters are cleaned by an air scour followed by up-washing of water. Experiments have been made to ascertain if the air scour could be dispensed with, but these have not pointed to any improvement in the results. In general, the grading of the sand for both rapid and slow sand filters varies, but the present specification is—

	Effective size	Uniformity coefficient
Rapid filters	0.80	1.6
Slow sand filters	0.29	1.6

The compression of the air is performed in closed cylinders by the water which is subsequently used to wash the filters and the percentage of wash water used is about 1%.

The capital cost of rapid filters is approximately 14,000 dollars per m.g.d. filtered or 50,000 dollars per 1,000 sq. feet of sand area.

FIG. 9.—FILTRATION PLANT AT KEMPTON PARK WORKS.
The primary or rapid filters in the background, slow sand filters in the middle distance, and chlorination house in foreground.

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The Board have inherited a peculiar legacy from the old Water Companies of a considerable number of slow sand filter beds of all shapes and sizes and often without adequate road access. Most of these were constructed at such a level that water could be admitted into them by gravity from either river. They are thus situated in waterlogged ground and when cracks or settlements develop with age, impure water finds its way into the underdrains. To avoid this, the latest filter beds have been constructed so that their bottoms are above the water table, though this necessitates an additional pumping lift.

The underdrains are composed of bricks, purpose-made tiles and, recently, a layer of "No Fines" concrete with channels cast in it has been successfully adopted with a considerable reduction in cost.

In the last few years the cleaning of the filter beds has been mechanised by the use of cranes, dumpers, tractors, etc., but this process has been greatly handicapped by the layout of the older works.

The present cost of an acre of slow sand filter beds is about 200,000 dollars or 45,000 dollars per m.g.d. filtered.

Micro-straining

During the last 10 years, self-cleaning micro-strainers have become available for the removal of algae, and the Board have experimented with these in substitution for the rapid filters, the water as usual passing to a slow sand filter bed after straining. The most recent development consists of a circular drum 10 ft. in diameter and 10 ft. in length covered with a mesh, which is protected on both sides, having apertures of 40 microns or about 80,000 per square inch. The raw water passes through the screen from the inside and the debris is caught on the screen and is carried round until it reaches the top, when it is washed off by jets of water into a collecting trough from which it runs away to waste. The great advantage of this apparatus is that the loss of head through it is about 6″ as against some 10′ for the rapid filter. On the other hand, measured by the quantity of water filtered per acre cleaned of slow sand beds, the strainers have not yet shown themselves so efficient as the rapid filter and, unlike rapid filters, no chemical action takes place while the water passes through them. It is, as yet, early to pronounce judgment on this type of plant,

but the Board are at present constructing two installations (combined with slow sand filters) of capacities of 108 m.g.d. and 54 m.g.d. respectively.

The cost of micro-strainers per m.g.d. filtered is at present about 6,000 dollars, including the building but excluding means of conveying the water to and from the plant.

The filtration operating costs are not excessive when related to the total costs of the Board, being at present about 800,000 dollars per annum or 3.2% of the total annual expenditure of the Board. This represents 6 dollars per million gallons supplied out of a total cost of 180 dollars per million gallons supplied.

Chlorination

The control of the chlorination of the water supplied by the Board is not the responsibility of the Engineer but of the Director of Water Examination, who is a Chief Officer of the Board with equal status and has charge of a fully equipped laboratory, centrally situated.

All river water is chlorinated after filtration, the average dose being 1 p.p.m. The standard practice is to allow one to two hours' contact time, but contact tanks have not yet been built at all the works and in such cases pre-filtration chlorination is carried out.

Chlorination is effected by applying sufficient chlorine to produce a pre-determined residual of free chlorine after a known period of contact. The dose varies from one works to another, but it is found that the establishment of 0.2 p.p.m. of free residual chlorine after a 10 minutes' contact produces a satisfactory water from the bacteriological point of view.

Chlorine is, in general, obtained in drums containing about 1,900 lbs. of the gas and the standard apparatus is purchased by contract.

At a number of works residual recorders are installed and the automatic control of the dosing instruments by the residual recorders is being developed.

The total amount of chlorine used per annum is about 550 tons, which averages out just under 1 p.p.m. over the whole supply. The cost of chlorine is 75 dollars per short ton in 1,900-lb. drums. The cost of chemical treatment, which includes sulphur dioxide and

the copper sulphating of reservoirs, is about 210,000 dollars per annum or 1.50 dollars per m.g. supplied.

Well Water

It is perhaps convenient at this juncture to refer to the treatment of the supply from wells, upon which over a million people depend.

About 25% of the water derived from wells is unsuitable for direct supply without filtration. The bulk of the water obtained from underground sources, however, is pumped directly to supply and is of such excellent chemical and bacteriological quality that doses of chlorine of the order of 0.1 p.p.m. would destroy any coliform bacteria in a matter of minutes. The urbanisation of the area adjacent to many wells has already been alluded to and, in consequence, larger doses of chlorine than are necessary are applied as a precautionary measure. The dose varies from 0.5 to 1 p.p.m. and de-chlorination is effected by sulphur dioxide after a minimum contact time of 20 minutes.

The standard arrangement at wells is to lift the water to the surface and pass it through a contact tank at atmospheric pressure. After treatment it is then pumped to supply by a force pump. At some of the older works, it is not possible to break the pumping into two lifts and contact tanks under delivery pressure have to be employed. This is not so satisfactory, as difficulty is frequently experienced in pumping or injecting the chemicals into the water.

Pumping

Since the water is derived from levels below the consumers, every gallon has to be pumped and there is no gravity supply in London. Pumping thus enters into every stage of the process and the duties of the pumping plant may be summarised as follows:

(a) *Raw-water pumping from the rivers to the reservoirs.*

Here the quantities are large and the heads are low, the capacities of the pumping units varying from 90 to 20 m.g.d., while the average head is about 40 feet.

(b) *Pumping to supply from filtration stations.*

The most modern steam-driven units have a capacity of 34 m.g.d.

against 280 feet head. No large electrically driven pumps have yet been installed, but units capable of pumping 36 m.g.d. against a maximum head of 320 feet are on order.

(c) *Re-pumping Stations.*

These are required for the supply of high and relatively large isolated areas, the units varying in capacity from 2 to 6 m.g.d. and the heads from 100 to 200 feet.

(d) *Well Pumping Stations.*

Here the standard practice (which, however, has not yet been established at all the works) is to lift the water to the surface, pass it through the contact tank, and then pump it to supply. The units have capacities of one to three or four m.g.d., the average lift from the well being about 100 ft. and the pressure of the delivery 220 ft.

(e) *Booster pumps for isolated and small high areas.*

(f) *Miscellaneous plant, e.g. low-lift pumps in filtration stations, etc.*

Policy Regarding Type of Plant to Be Installed

On account of the importance of maintaining the pumps in continuous operation, the Board have felt that the sources of power should be under their absolute control, and up to the war, with but very few exceptions, steam or oil driven pumps were installed. Recently, however, this policy has been modified and electrically driven pumps operated by purchased current have been employed. Except, however, at stations of minor importance or those at which the duty can easily be taken over by other works, about 100% oil engine driven standby plant has been provided where purchased electricity is used.

In connection with the supply of fuel, it has to be remembered that, in Britain, all oil has to be imported and in adopting their policy, i.e. the use of purchased current as the main source of power, the Board realise that their plant is not so self-contained as it would be if it consisted of steam engines and boilers for which a suitable stock of coal could be carried. On the other hand, electrical drive is the most economical means of pumping.

As might be expected, almost every type of pumping engine has been employed during the last 250 years, but the bulk of the pumping

is still performed by steam, mostly by vertical triple-expansion engines or steam turbines. At the present time the Board operate some 115 pumping stations (counting each building housing pumping plant as one). They vary in output from Hampton (Fig. 10), with 15,000 W.H.P. and an installed pumping capacity of 347 m.g.d., to small booster stations of 1 W.H.P. or less pumping about 30,000 gallons per day. The percentage of pumping performed by various types of power (based on W.H.P. in 1951-52) is:

Steam (coal-fired boilers)	68%
Oil engines	9%
Purchased electricity	23%

At a new pumping station under course of construction, the total installed W.H.P. of electrically driven pumps will be about 14,500 and for standby purposes generating plant of some 10,500 Kw. is being provided, of which 7,250 Kw. will be produced by 3 gas turbine sets and the remainder by 3 diesel engines. At this station roto-valves will be used for the first time to protect the mains and pumps from damage by surges, caused by failure of the power.

At the present time the economic situation does not permit of the building of new pumping stations and, when replacements are made, the plant has often to be installed in existing houses (Fig. 11) which are frequently unsuitable for the new and small pumping machinery. However, the economic situation being what it is, this procedure has to be accepted.

The total quantity passed through the pumps in the year 1951-52 was approximately 386,000 m.g., i.e. each gallon of water was pumped 2.7 times.

The cost of pumping is the largest single item (except interest and debt charges) in the Board's annual expenditure, being 4,500,000 dollars. This represents nearly 18% of the total expenditure and about 32 dollars per m.g. supplied.

Coal now costs 10.7 dollars per short ton, oil 37 dollars per short ton, and the average price of purchased electricity is 1.2 cents per Kw. hour.

It should again be stressed that the maintenance of the supply depends entirely upon the continuous operation of the pumps, since many of the service reservoirs are too low and too far from the

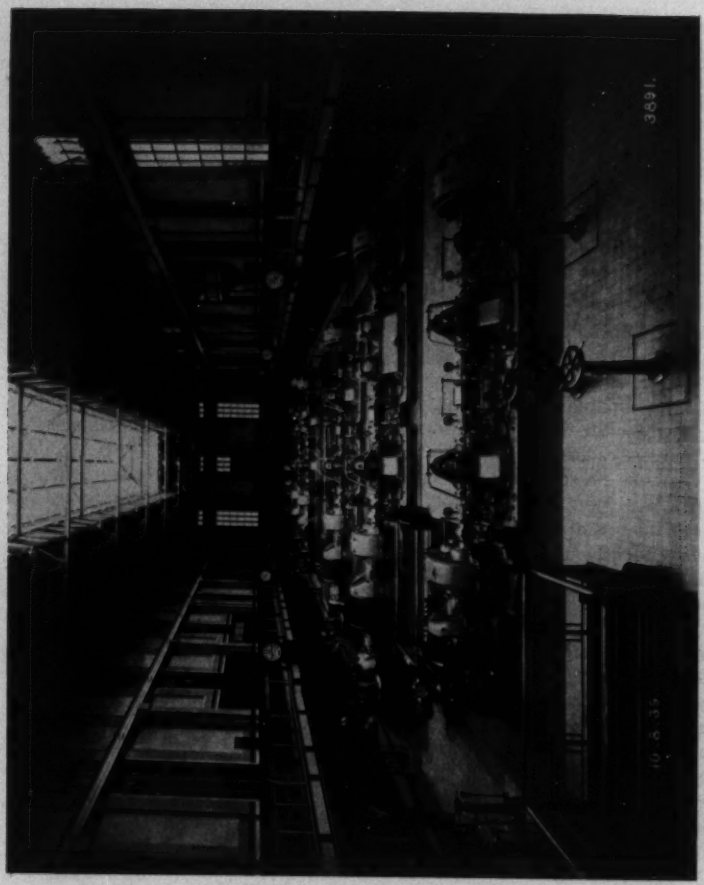

FIG. 10.—INTERIOR VIEW OF PUMPING STATION, HAMPTON.
Eight (seven only shown in photograph) steam turbines, driving centrifugal pumps and generators.
Installed water and electrical horse power—15,000. Total capacity—347 m.g.d.

FIG. 11.—ELECTRICALLY DRIVEN PUMP, BROXBOURNE WELL STATION.
This photograph shows the installation of new machinery in an old and unsuitable building, on account of the restrictions on the new constructional work.

pumping plant to supply sufficient water back if the pumps fail. In other words, the hydraulic gradient necessary to maintain the requisite pressure in most of the mains is dependent upon the pumps and not upon the service reservoirs.

Distribution

The distribution of water to the Board's 6½ million consumers is effected through some 8,500 miles of main, varying from 2″ to 48″ in diameter. For some years, however, no mains smaller than 4″ in diameter have been laid and in the near future mains of 54″ and 60″ diameter will be brought into operation. Of the total mileage of distribution mains, 5,250 miles are 4″ in diameter or less and the length of pipe 24″ in diameter or over is 580 miles. Practically all the distribution system is laid with cast-iron pipes and less than 50 miles of steel pipe lined and sheathed with bitumen are in use or are about to be brought into use.

Fortunately, the water supplied by the Board is not aggressive to cast iron and, in general, only coats the interior of the pipes with a thin deposit of lime. With regard to external corrosion, there are, however, large areas of yellow clay in which graphitisation occurs, while in parts of London, especially near the river where the ground has been made up, external corrosion is experienced. The remedy which has been adopted has been to protect new cast-iron pipes laid in such areas by a bituminous sheathing, ⅜″ in thickness or thereabouts. Until recently, all joints were made with run lead, but with steel mains, welded joints or Johnson (Dresser) couplings have been used and for the cast-iron pipes patent joints are now frequently employed.

Since it is not possible to make good the lining at joints inside a pipe smaller than 24″ in diameter, steel pipes are not laid in sizes below this, but spun iron pipes are employed. No problem of the freezing of the water in mains occurs and these are now laid to a minimum depth of 2′6″ for small pipes and 4′ for larger pipes. There are, however, many mains in the older parts of London which are laid at considerably less depths. About 2,000 bursts occur per annum, or one for every 4¼ miles of main. They are due to a variety of causes, the principal being the admission of cold water from the filters into the mains in frosty weather, which results in contraction frac-

tures, especially where the pipes are weak and corroded. It is an interesting fact that in areas where well water of an almost constant temperature of about 50° F. is pumped into the mains, practically no bursts arise during periods of cold weather.

Owing to the congestion of pipes and apparatus beneath many of the streets, especially in the centre of London, an example of which is shown in Fig. 12, the Board are considering the laying of large mains in deep tunnels in the London clay (which when solid is an admirable material for this purpose), and the 75″ main, to which reference has already been made, is to be laid in this manner for the conveyance of unfiltered Thames water to the works in the valley of the River Lee, where supplies are short owing to the failure of that river. This main will be about 21 miles long and an experimental section, about 1,000 feet in length, has already been laid beneath one of the Board's works at a depth of approximately 100 feet below the surface.

The tunnel was driven by a shield of 102 inches diameter and was immediately lined with pre-cast wedge-shaped concrete segments, 5 15/16″ in thickness. Later, a ½″ steel pipe, 77″ in internal diameter, and lined with 1″ of concrete, was drawn in and the joints welded internally. The annular space of 6″ was then filled with grout. The total cost of this length was approximately 198,770 dollars or approximately 600 dollars per yard run. As a result of experience gained from this experimental length, the final design for the main will probably be modified to a considerable extent.

The Board have 79 covered service reservoirs and 6 elevated tanks or water towers containing together about 306 m.g. and, as has already been remarked, most of these reservoirs merely act as jack heads and are unable to take over a large proportion of the supply.

In general, the pressure in the service mains is about 80 to 100 feet, but there are parts of London where this is as low as 50 feet. There are some 73,000 public fire hydrants on the Board's mains which are owned by the Board but constructed and maintained at the cost of the Fire Brigades.

In recent years, all mains have been sterilised by chloros or gaseous chlorine after laying or after they have been broken into for repair purposes, and sterilised yarn is used in making socket and spigot

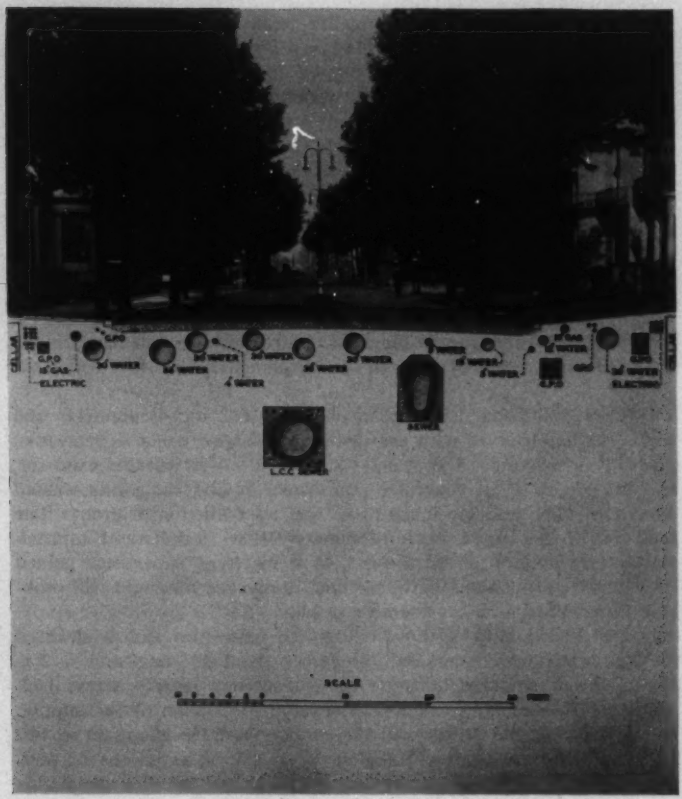

FIG. 12.—COMPOSITE PHOTOGRAPH AND DRAWING SHOWING CONGESTION OF MAINS, ETC., UNDER A ROADWAY IN WEST LONDON.

In this Figure 1-36″ and 6-30″ water mains, 2 sewers, as well as many smaller mains, telephone ducts and electric cables are shown. The mains were laid in the horse and cart era, and this explains the shallow cover.

joints. In the case of mains of 12" in diameter or over, samples are always taken and the main is not put into service—except in cases of emergency—until it is confirmed from the laboratory that the water is satisfactory.

* * *

In this Paper an attempt has been made to give a brief description of the practices adopted by the Board and the reason why various processes are employed. It must be remembered that the Board are handicapped by having to operate a system of supply which has grown up haphazard during a period of about 150 years and, in consequence, has not been laid out on any particular system. Nevertheless, since their inception, the Board have done much to unify the supply to London, and if proof is needed of their success it can be stated that, in spite of two wars and national financial difficulties, there are practically no complaints of shortage of water, that the supply for essential purposes has always been maintained even in drought years, and that the percentage purity of the water delivered from the works, measured in terms of samples containing no B.Coli in 100 ml., was 99.8 in 1951-52.

In conclusion, the Author gratefully acknowledges the help and advice which he has received, in preparing this Paper, from his colleagues on the staff of the Board, both in the Engineer's and Clerk's Departments, and also from many friends who have so kindly supplied him with information.

GUIDES FOR SELECTION OF CHEMICAL FEEDERS

BY PAUL A. COFFMAN, JR.*

[*Read September 8, 1952.*]

At some time in his career, nearly every water-works' operator is faced with the problem of designing a chemical-feeder installation and selecting and purchasing equipment. The success of that feeder installation depends largely upon the thought and study given to the problem before equipment is purchased.

The science of handling and proportioning chemicals for water treatment has advanced to the point where standard equipment is available from several manufacturers for practically any feeding problem. The choice or selection of chemical-feeding equipment to fit a particular situation likewise can be standardized within certain limits and it has been possible to develop certain guides for the selection of this equipment.

Once the process to be used has been decided on with competent technical advice from the consultant, it is time to select chemical-feeding equipment. Such advice should include a decision as to the chemical to be used, whether it will be fed in dry or liquid form, and point of application, and due consideration of availability, cost, quantities to be handled, solubility and stability of the chemicals which can be used.

The present paper deals with guides for selection of dry chemical-feeding equipment. A future paper will deal with liquid feeding equipment.

There are eight principal guides for selecting dry chemical-feeding equipment:

1. Define operational requirements.
2. Determine storage capacity required.
3. Choose best available location.
4. Choose type of installation.
5. Choose type of feeder.

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6. Select accessories necessary.
7. Furnish information to manufacturer.
8. Evaluate proposals.

Guide No. I—Define Operational Requirements

1. Determine the feed-rate requirements for the installation. It is important to give careful consideration to the actual maximum and minimum rates of feed required. If minimum and maximum rates required are not carefully determined, it may force equipment manufacturers to offer larger or more expensive equipment than is actually needed for the job.

2. Decide on the degree of accuracy required. If the process is critical and chemical feeding must be precise, a tolerance of plus or minus one per cent is probably all that can be allowed and gravimetric feeders must be used. On the other hand, if the chemical treatment required can vary somewhat, without seriously affecting the process, and considerable retention period is available for ironing out variation in dosage, then a feeding accuracy of 3 to 5% of the feed rates may be satisfactory and volumetric feeders can be used.

3. Decide on the records which will be required for this process. If it is desirable to have totalizers and recorders, then gravimetric feeders should be specified. A log-sheet record can be had with volumetric feeders, provided they are installed on platform scales. If no scales are furnished, then the only reliable record will be an accurate count of bags of material used on a daily basis. For very low feed-rate installations, the bag-count method will not be satisfactory, because only one or two bags of chemical will be used in a 24-hour period.

4. Decide on the type of controls required for the installation. This includes a decision on whether the equipment will be manually controlled or automatic. If the rate of flow through the water plant varies considerably, then proportional pacing may be required. If the feeder installation is for a well station, automatic start-stop control in parallel with pumps may be desirable. For some installations where the feeder is to be installed in a rather isolated location or where man-power is limited, remote control of the feeding equipment may be an economic necessity.

Guide No. II—Determine Storage Capacity Required

1. Storage in a chemical-feeder installation is an important consideration from the standpoint of labor saving and purchase of chemicals in economical quantities. All feeders should have an initial hopper capacity, equivalent to not less than four nor more than 24 hours' storage when feeding at the maximum required rate of feed. If manpower for dumping chemicals is available on all three shifts, then four to eight hours' capacity will be satisfactory; otherwise, provide capacity for 24-hour operation.

2. Bag- or bulk-storage capacity must be determined on the basis of economical purchase and transportation quantities, and time required for delivery from suppliers. Sixty to ninety days' supply is the usual bag- or bulk-storage requirement. If the chemical is to be stored in bags, due consideration must be given to the floor space required for such storage and means for handling the bags in the most economical manner.

All bag chemicals should be stored on pallets, to keep them dry, and the chemical storage space should be a well-ventilated area, to prevent chemical from absorbing moisture during storage and becoming difficult, if not impossible, to feed satisfactorily in dry feeders. If more than a few bags of chemical per day are to be handled, it may be economical to provide lift trucks for transporting the pallets of bagged chemical from one feeder installation to another.

3. When the chemical is to be stored in bulk, bins must be large enough to hold at least one and one-half times the normal shipping quantity. If the water plant is a great distance from the source of supply, there is a chance of delay in transit and additional storage capacity should be provided, so that there will be no danger of the plant's running out of chemical between shipments. The usual practice is to provide a minimum storage capacity of one and one-half to two carloads when chemical is purchased in bulk.

Guide No. III—Choose Best Available Location

1. The hydraulics of a chemical-feeder installation should be studied very carefully before selection and purchase of equipment and solution lines. Whenever possible, choose a location that will permit the dry chemical to flow entirely by gravity from the storage

level to the feeder and dissolving chamber; then by gravity from the solution chamber to the point of application. Such accessories as conveyors, pumps and ejectors should be eliminated, if possible.

2. If a location is not available with these ideal conditions, then choose the location that will require as little pump or ejector head as possible. This is particularly important in the feeding of alkaline chemicals, when hard water is used in the dissolving chamber. Pumps and ejectors on chemical-solution lines always require frequent cleaning and servicing, and their use should be avoided whenever possible.

Guide No. IV—Choose Type of Installation

There are four basic types of dry chemical-feeder installations:

1. *Small Unit Feeder* (Fig. 1), used when a very low feed rate and small chemical-storage capacity are required. The principal parts are feeder hopper, feeding mechanism, means for feed-rate adjust-

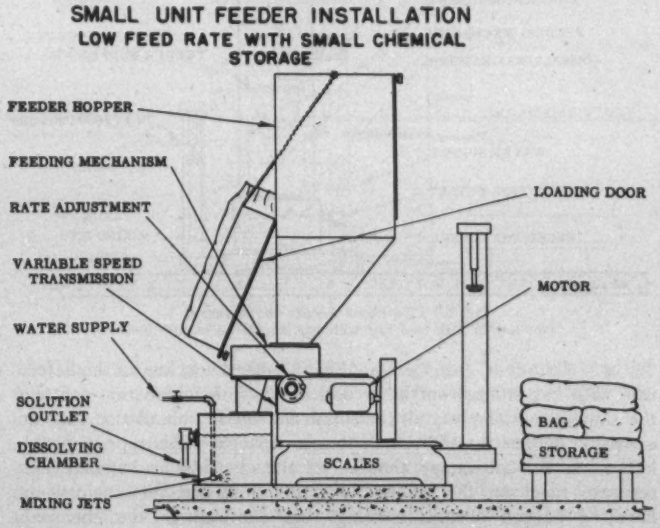


Fig. 1.—Small Unit-Feeder Installation.
(for low feed rate with small chemical storage)

ment, variable-speed transmission or equivalent, water supply for mixing jets in dissolving chamber, dissolving chamber sized for adequate detention for the chemical being fed, and platform scales for an accurate check on the performance of the equipment.

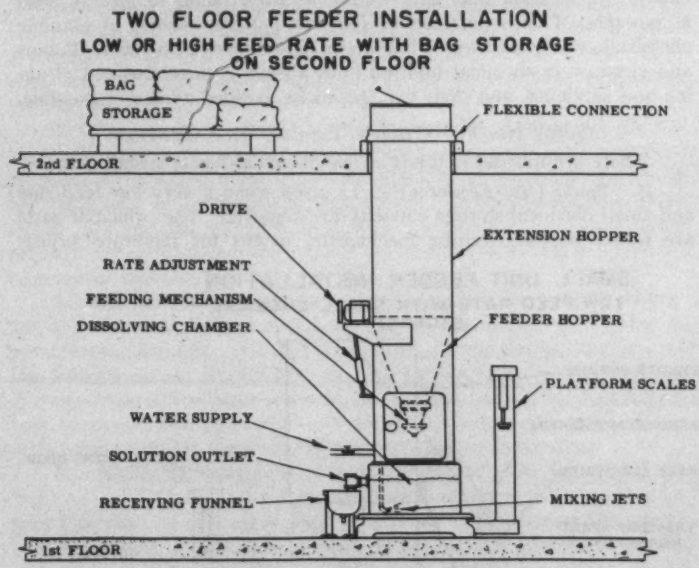


FIG. 2.—TWO-FLOOR FEEDER INSTALLATION.
(for low or high feed rate with bag storage on second floor)

2. *Two-floor Installation* (Fig. 2), used for low or high feed rate with bag storage on the second floor. This installation contains the same essential parts as the small unit-feeder installation plus an extension hopper for additional storage capacity. This type of installation has the advantage that all of the chemical is handled in a separate room on the second floor, the dust and dirt incident to handling bagged chemicals being thus confined to the chemical-

storage room. An ideal refinement, highly desirable but not absolutely essential, is a dust collector installed on the extension hopper at the second-floor level, to eliminate dust in the chemical-storage room while loading the hopper.

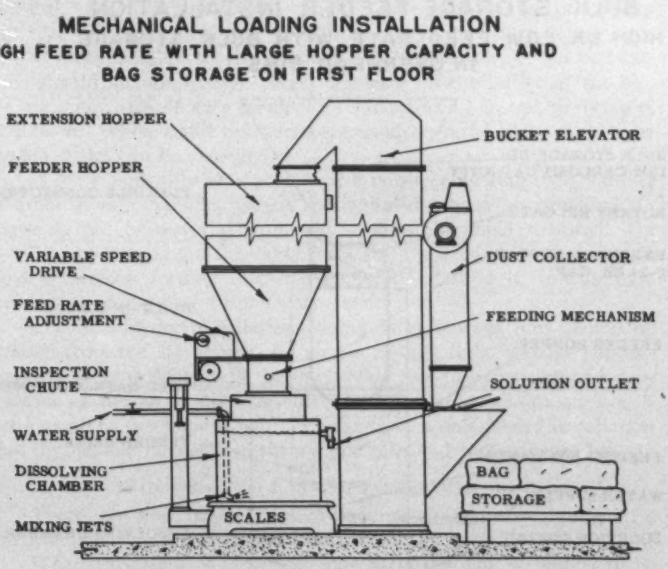


FIG. 3.—MECHANICAL LOADING INSTALLATION.
(for high feed rate with large hopper capacity and bag storage on first floor)

3. *Mechanical Loading Installation* (Fig. 3), used when the feed rate is high and large hopper capacity is required with bag storage on the first floor. Here again, the essential parts of the unit-feeder installation are included plus an extension hopper, bucket elevator and dust collector. This type of installation is frequently used when new and larger-capacity equipment is installed in an existing chemical building. It is also used for new installations

with adequate floor space available on one floor for the equipment and chemical storage. (Considerable savings can sometimes be realized by eliminating the second floor of the chemical building.)

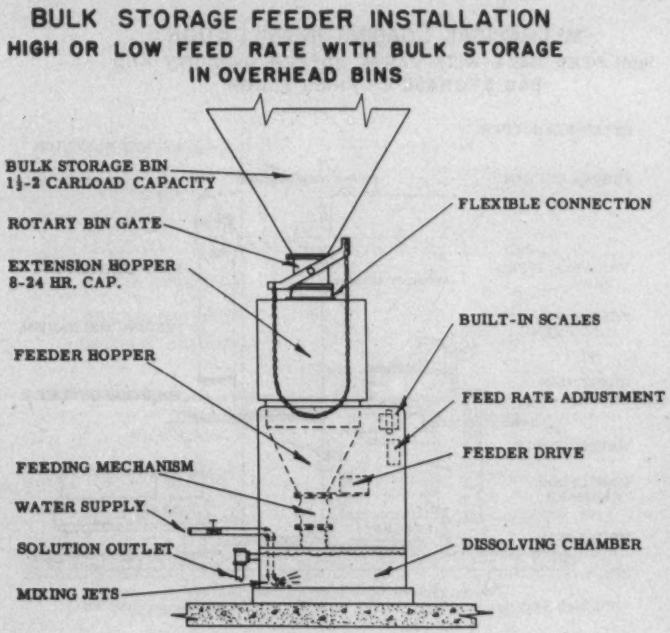


FIG. 4.—BULK-STORAGE FEEDER INSTALLATION.
(for high or low feeder rate with bulk storage in overhead bins)

4. *Bulk Storage-Bin Installation* (Fig. 4), used for high or low feed-rate requirements, where chemical is purchased in bulk, usually truckload or carload quantities, and stored in overhead bins. This type of installation is used mostly by large plants where it is economical to purchase chemicals in bulk carload quantities.

These storage bins are usually constructed of concrete or steel and are an integral part of the building. It is considered good practice to make the lower section of the storage bin of steel so that vibrators, plate-type agitators or other agitating devices can be readily installed. Any bin installation can be made suitable for practically any type of chemical feeder, by fabrication of the steel hopper section to meet installation requirements. All large storage-bin installations should include a large rotary bin gate on the outlet of the bin, the minimum size of gate being 9 x 15 in., 12 x 12 in. or, preferably, 12 x 24 in. When small bin gates are used on large bins, packing at the bin outlet can be expected.

If the chemical to be stored is of a non-free-flowing type, subject to arching and flooding, means for agitation must be provided, to insure a flow of material from the storage bin when required. On installations handling a floodable material, the feeder selected should have a rotolock feeding mechanism incorporated in it, to eliminate the danger of flooding through the feeder.

Chemical-feeder installations under large storage bins should be isolated from the storage bin by means of dust-tight, flexible connections, to prevent damage to the equipment due to expansion and contraction of the large storage bin. The installation shown on Fig. 4 contains all of the same essential elements of a unit-feeder installation plus the flexible connection, rotary bin gate and bulk storage bin.

Guide No. V—Choose Type of Feeder

There are two basic types of feeding mechanisms: volumetric and gravimetric.

When variations of 3 to 5% plus or minus (by weight) can be tolerated in the feed rate and when it is not necessary accurately to record or totalize the actual weight of material fed, then volumetric feeders may be used. When more accurate feed rates (within plus or minus one per cent by weight) are desired and when automatic control of feed rate and accurate records of feed rate are required, then gravimetric feeders may be used.

Volumetric Feeders

Volumetric feeders are designed for volume displacement. They do not incorporate scales in their feeding mechanism. If scales are

used, they are usually platform scales supporting the entire machine and its contents.

Such scales give a check on the performance of the machine, but do not actually control the rate of feed. Any changes in density or feeding characteristics of the chemical being fed will directly affect the actual weight of material fed. Inasmuch as volumetric feeders measure only the volume displaced, and not the weight of the material, it is possible for a volumetric feeder to operate mechanically without actually feeding any material, and there is no means of warning the operator if material is not being fed. For these reasons volumetric feeders usually require more attention from the operators, to insure continuous satisfactory operation of the process.

Volumetric feeders can be used in small plants where:

1. Operation rates are relatively constant.
2. Continuous check on performance of the equipment is possible—for example, regular visits by the Operator every half-hour or hour, and checking the material fed by means of platform scales.
3. Considerable retention capacity in the mixing and settling basins is available to average minor variations in feed rate, due to changes in bulk density or feeding characteristics of the chemical.

Typical volumetric feeders include the Omega Universal, Rotolock, and Disc Feeders, Wallace & Tiernan Series A-635, Type NA and Type A-552, Infilco Type D and Type E, and Syntron Vibratory Feeders.

The Omega Universal Feeder (Fig. 5) is readily adaptable for feeding any of the dry chemicals used in water plants. The feeding mechanism is of the large, open, oscillating-throat type. It is accurate volumetrically and is not readily plugged by lumps or trash. Rate of feed is adjustable over a wide range. These machines are manufactured in three sizes, with suitable accessories for any of the four types of installations previously described. The principal advantages of using this type of machine are: low first cost, simple operation, and low maintenance service.

The Wallace & Tiernan Volumetric Feeder, Series A-635 (Fig. 6),

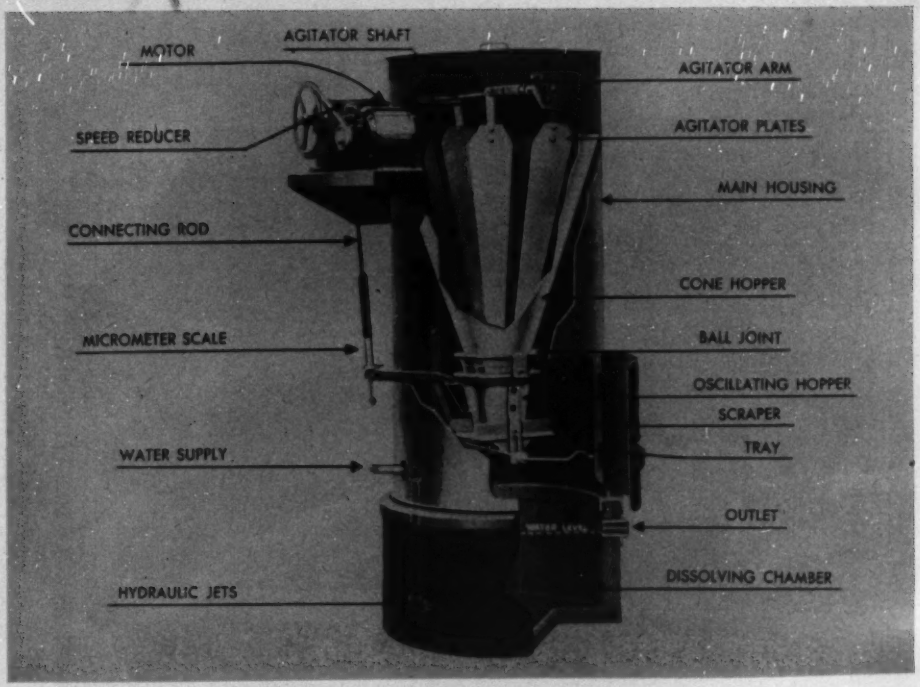


FIG. 5.—OMEGA UNIVERSAL VOLUMETRIC FEEDER.

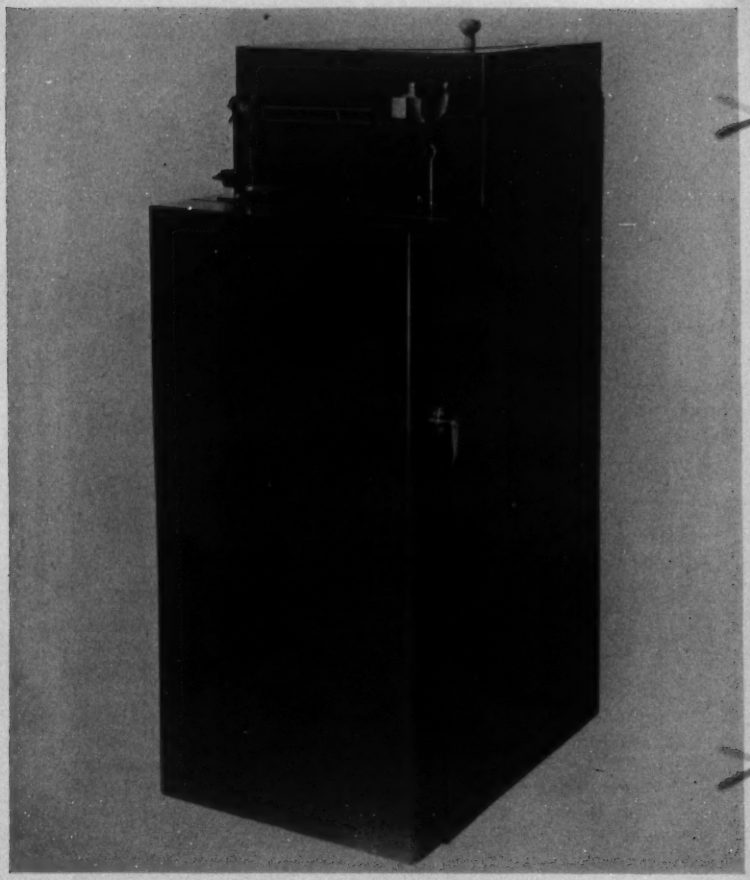


FIG. 6.—WALLACE & TIERNAN SERIES A-635 VOLUMETRIC FEEDER (with scales for weight checks).

incorporates a feeding mechanism of the horizontal-screw type, utilizing a combination of rotary and axial movement through a feed trough discharging chemicals at both ends. The rate of feed is regulated by a cam-operated clutch mechanism, by means of a control crank. This machine is primarily offered for unit-type installations.

The Wallace & Tiernan Type NA Feeder consists of a slow-moving feed roll, delivering a ribbon of chemical across the feed apron, from which it is fed to point of discharge. Changes of feed rate are made by varying the width of the ribbon and by change gears. The Wallace & Tiernan Type A-552 Feeder has the same type of feeding mechanism as the Series A-635 Feeder.

The Infilco Volumetric Feeder, Type D (Fig. 7), is a disc-type (revolving table) feeder, in which the position of a feed knife on the disc determines the rate of feed. The Type E machine (Fig. 8) is an extrusion-type feeder, with a feed pan underlying the hopper and moving with a rocking and reciprocal motion. These machines are primarily used for small unit-feeder installations.

The Omega Rotolock Feeder (Fig. 9) is a star-wheel or pocket-drum type of feeder and is recommended for volumetric feeding of floodable materials, such as hydrated lime, activated carbon, clay, etc. The feeding mechanism is entirely enclosed and is driven by an infinitely variable-speed transmission (100 to 1 range). It is available with electric or pneumatic rate-setting devices, for use with automatic pH controllers and proportional pacing systems. Accessories for the Rotolock Feeder are available for all four types of installations.

Omega Disc Feeders (Fig. 1) are used for feeding finely ground materials continuously and accurately at very low rates of feed. When the maximum feed rate required is less than 50 lb. per hour, the disc-type feeder should be considered. The feeding disc has a scroll-type feeding orifice, which provides exact volumetric measurement. Delivery of material is continuous, even at very low rates, and directly proportional to the number of revolutions of the disc. An infinitely variable-speed drive rotates the disc at the desired speed. Machines with a feeding range as low as one to 25 ounces per hour are available. This machine may be equipped with any of several sizes of feeder hoppers, including the loading-door hopper, all suitable for hand filling from feeder-room floor. This machine is gener-

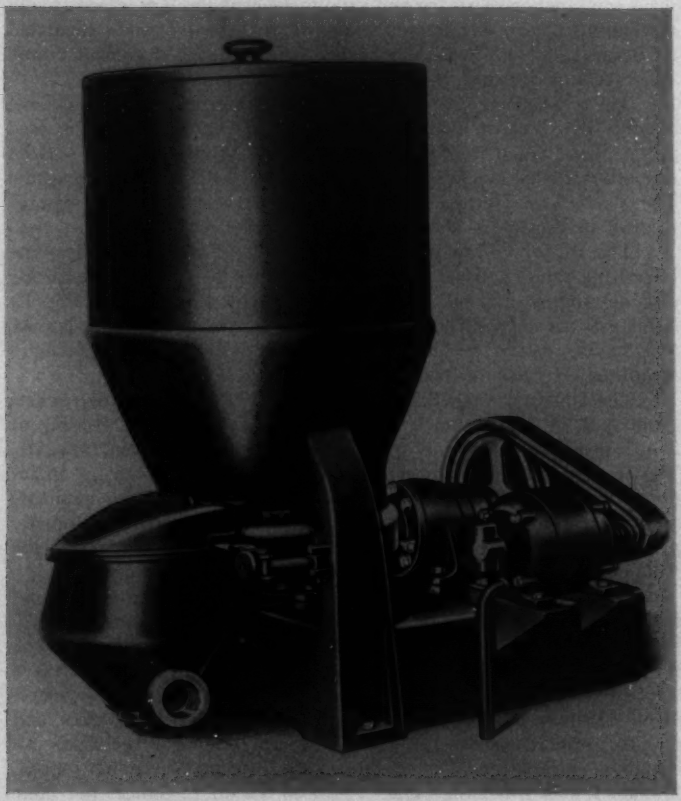


FIG. 7.—INFILCO VOLUMETRIC FEEDER, TYPE D, WITH REVOLVING TABLE.

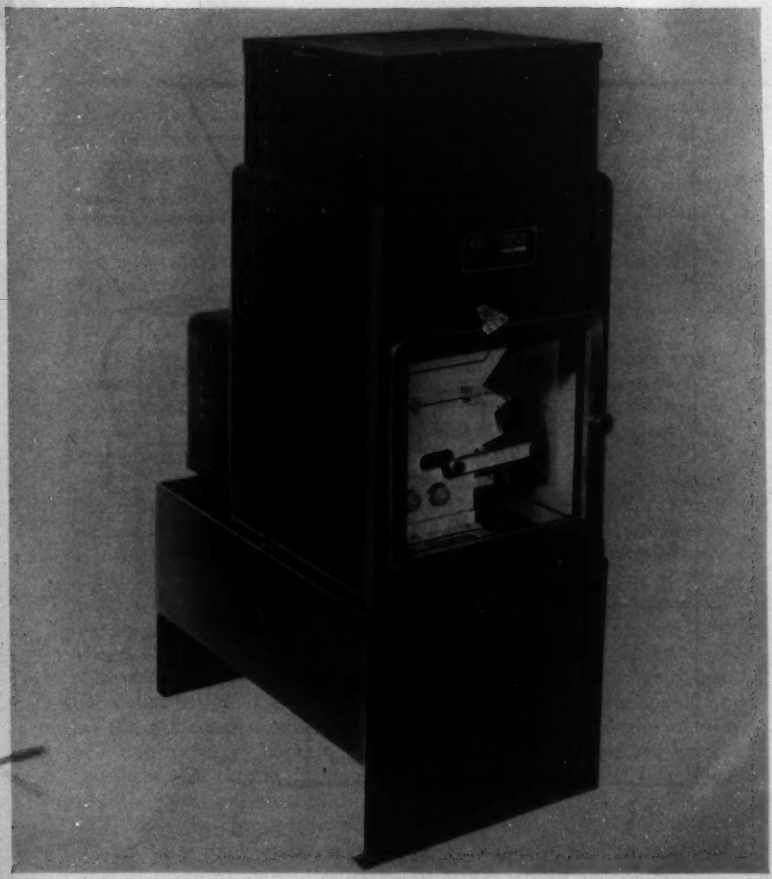


FIG. 8.—INFILCO VOLUMETRIC FEEDER, TYPE E, WITH ROCKING FEED PAN.

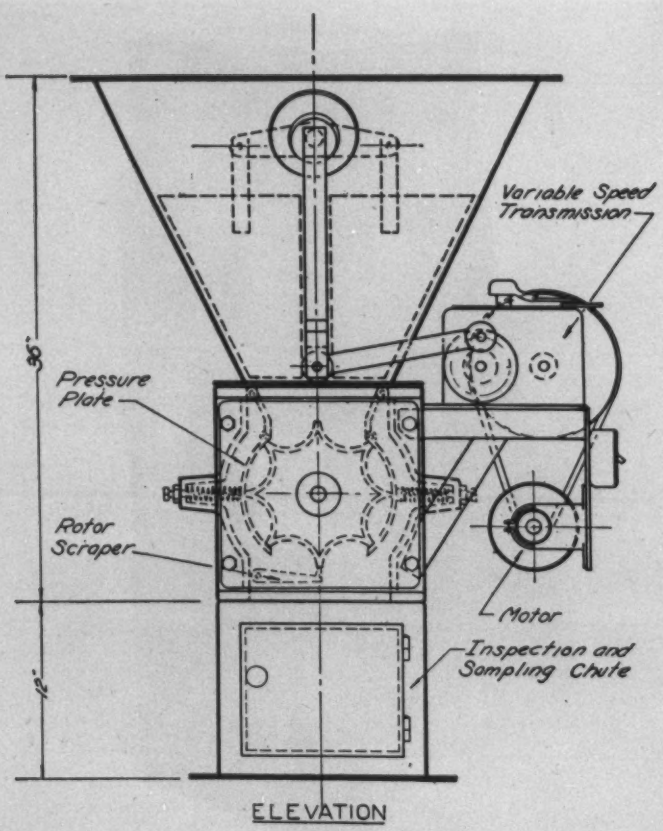


FIG. 9.—OMEGA ROTOLOCK FEEDER.

ally used for unit-feeder installations requiring low feed rates and small chemical-storage capacity.

Gravimetric (Weighing) Feeders

Gravimetric or weighing feeders are machines designed to feed dry chemicals continuously and accurately by weight. They are to be preferred because of their greater feeding accuracy and wide feeding range, and because automatic controls, alarm devices, totalizers and recorders are readily incorporated into the machine. The rate of feed can be pre-set and the feeder will maintain its set rate of feed by weight, regardless of changes in bulk density or flowing characteristics of the chemical being fed. Such feeders are easily fitted with accessories for accurate automatic proportional pacing from flow meters.

Gravimetric feeders are manufactured in two types: belt gravimetric and loss-in-weight gravimetric feeders. Typical belt-type gravimetric feeders include the Omega "Chemizer," the Wallace & Tiernan Merchen Feeder, the Jeffrey Waytrol, and the Syntron Belt Gravimetric Feeder.

The Omega Chemizer (Fig. 10) is a belt gravimetric feeder. Dry chemical enters the feeder at the top, either from an extension hopper or from a chute, and passes to the feeding mechanism, where it is fed to the scale-supported weigh belt, which delivers the chemical to the outlet of the feeder. The scale controls the feeding mechanism, to maintain a precisely uniform weight of chemical on the weigh belt, regardless of changes in density. Adjustment of the feed rate of the Chemizer may be made in two ways: by setting the counterpoise weight on the scale beam, to increase or decrease the weight on the weigh belt, and allowing the belt to run at a constant speed; or by the preferred method of maintaining a constant weight on the belt and varying the belt speed. The scale beam and suspended Omega wedge control the amplitude of vibrations of the feed tray, which delivers chemical to the weigh belt.

When the chemical to be fed is compressible, finely ground and subject to arching and flooding from a storage hopper, a non-flood rotor is installed above the feed tray in the feeding mechanism.

The Wallace & Tiernan Merchen Feeder (Fig. 11) is of the belt

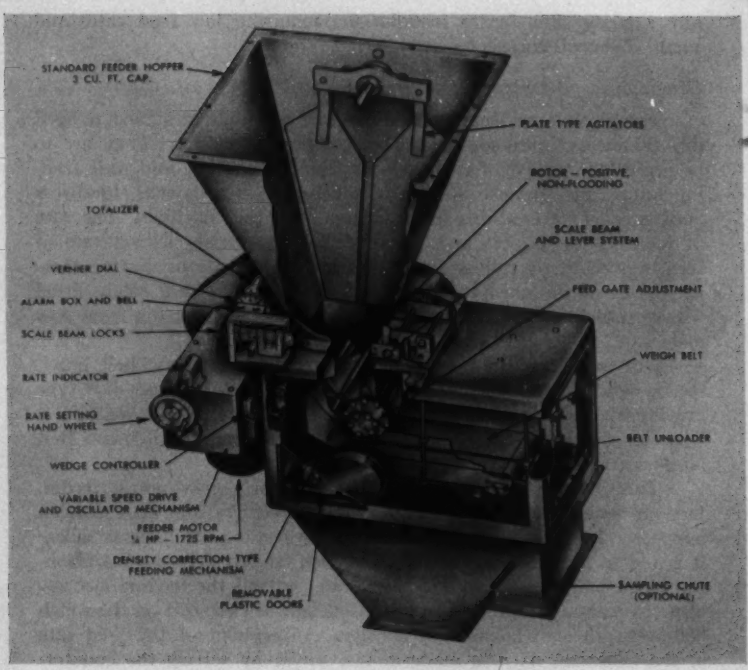


FIG. 10.—OMEGA "CHEMIZER" (BELT GRAVIMETRIC FEEDER) WITH POSITIVE NON-FLOOD ROTOR.

gravimetric type. It incorporates a weigh span between the head and tail rollers of a small conveyor belt, and mercury switches, actuated by the scale beam, increase or decrease the opening of the feed gate, to vary the load on the weigh span. Rate of feed is usually set by adjusting the weight on the scale beam.

The Syntron Belt Gravimetric Feeder (Fig. 12) consists of a short, constant-speed conveyor belt, supported by a small platform scale, an electric vibratory feeding mechanism, and electric or pneu-

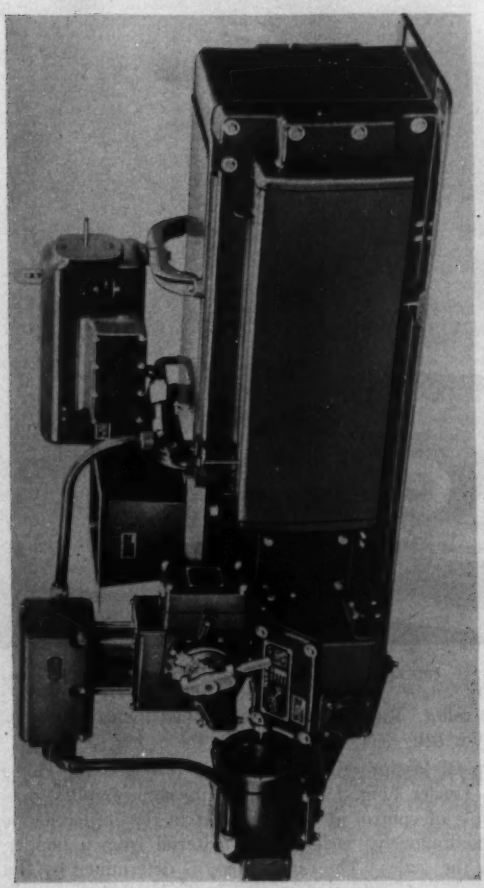


FIG. 11.—WALLACE & TIERNAN MERCHEN (BELT-TYPE GRAVIMETRIC) FEEDER.

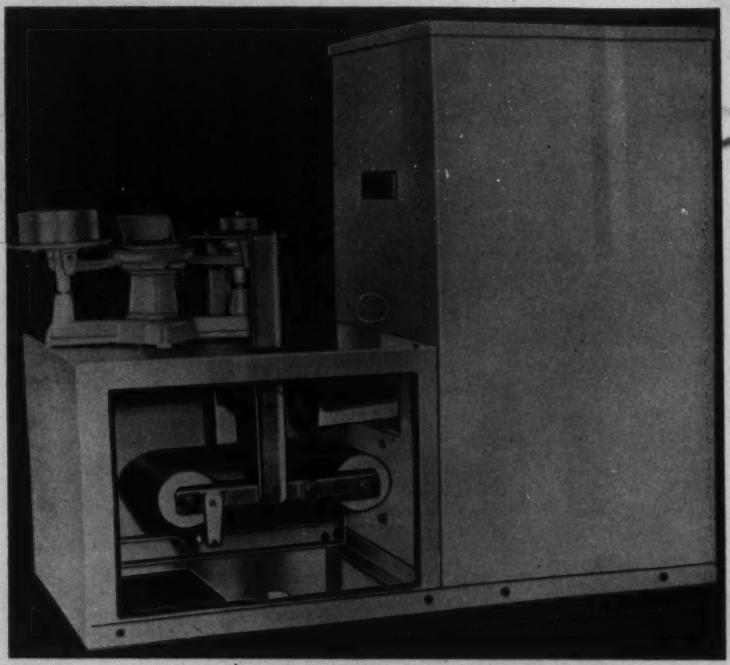
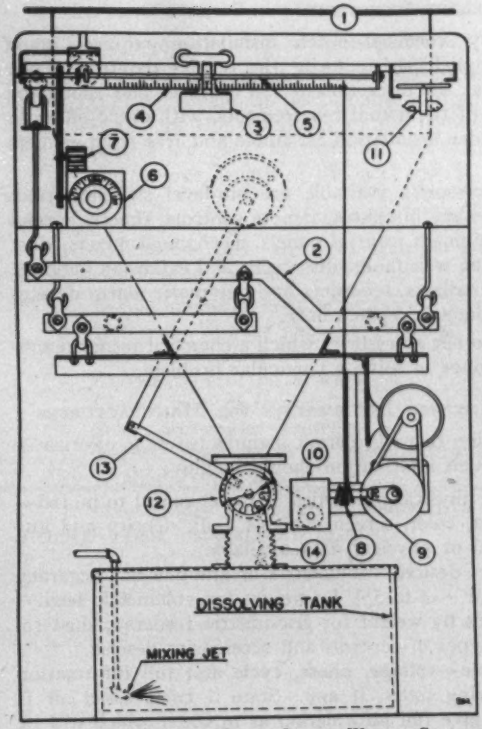


FIG. 12.—SYNTRON BELT-TYPE GRAVIMETRIC FEEDER.

matic controller. Rate of feed is controlled by varying the load on the conveyor belt.

A typical loss-in-weight gravimetric feeder is the Omega Loss-in-Weight Feeder (Fig. 13) which, as its name implies, operates on the principle of control of loss-in-weight in the feeder hopper. This machine continuously "weighs out" material from a hopper that is carried on the scales. The rate of feed is determined by the rate at which the poise is retracted on the scale beam by a mechanically



1. Hopper
2. Scale System
3. Poise
4. Scale Beam
5. Lead Screw
6. Lead Screw Drive
7. Totalizer
8. Wedge
9. Oscillator
10. Rotatrol
11. Alarm Switch
12. Rotolock Feeder
13. Agitator Levers
14. Flexible Connection

FIG. 13.—OMEGA LOSS-IN-WEIGHT GRAVIMETRIC FEEDER.

driven lead screw. Any departure of the beam from exact balance position causes an immediate change in speed of the Rotolock feed mechanism, either faster or slower, as required to maintain the scales in balance. The change in speed is effected effortlessly through the Omega wedge control device and the Rotatrol mechanism, that converts oscillating motion to progressive rotary motion. The Rotolock feeder cannot flood.

Guide No. VI—Select Accessories for Desired Operations

Practically every chemical-feeder installation requires some accessories, to accomplish satisfactorily the results required. Such accessories are used at the discretion of the engineer and should be selected on the basis of the actual requirements, with every effort to keep the chemical-feeder installation as simple and free from gadgets as possible.

Some of the accessories available are bin-level switches, pilot lights, belt shifters, rotary bin gates, remote controls, timers, special electrical starting equipment, control panels, mechanical mixers, dust collectors, proportioning weir tanks, dissolvers, and extension hoppers. Accessories such as totalizers, recorders and automatic alarm devices are available on gravimetric feeders only.

There are many other accessories which a chemical-feeder manufacturer can usually offer to solve a particular problem.

Guide No. VII—Furnish Information for Manufacturers

Furnish information that will permit manufacturers to offer satisfactory equipment. Such information should include:

1. Chemical and physical properties of the chemical to be fed—name, formula, color, screen analysis, bulk density and any other chemical or physical data available.
2. Type of feeder desired—volumetric or gravimetric; accuracy required (+ or —3 to 5% by weight for volumetric feeders or one per cent by weight for gravimetric feeders); dust removal units, types of controls and accessories desired.
3. Power available—voltage, phase, cycle and full information on special wiring codes, if any. State if compressed air is available and give full information as to water which will be used, including temperature, pressure and hardness, if possible. Be sure to mention any special chemical or physical properties of the water to be used.
4. General information—include such items as sketches or drawings of space available; indicate bins, hoppers or other equipment, existing or to be built, which may affect the engineer's recommendations.

Guide No. VIII—Evaluate Proposals

Give full consideration to these questions:

1. Does the equipment meet the specifications?
2. Will it provide the performance desired?
3. What are the economics of the installation? Consider economics not only the first cost, but also cost of maintenance and service, length of life, and cost of operation.

Summary

To summarize, there are eight principal guides for selecting dry chemical-feeding equipment:

1. Define operation requirements;
2. Determine storage capacity required;
3. Choose best available location;
4. Choose type of installation;
5. Choose type of feeder;
6. Select accessories desired;
7. Furnish information for manufacturers;
8. Evaluate proposals.

If these guides are carefully followed, a very satisfactory dry chemical-feeder installation is assured.

MEMOIR OF SCOTT KEITH

Scott Keith, member of the New England Water Works Association since 1925, a partner of the engineering firm of Metcalf & Eddy, died suddenly of a heart attack at his home in Newton Highlands, Mass., on July 4, 1953. He was born in Newton, Mass., February 18, 1898, the son of the late Dr. Frederick S. and Mary B. (Forbes) Keith.

Keith graduated from the Civil Engineering course at the Massachusetts Institute of Technology in 1919, receiving concurrent degrees of Bachelor of Science from M.I.T. and Harvard. He was a member of the Delta Kappa Epsilon Fraternity. In 1919-20 he was an assistant in the Civil Engineering Department at M.I.T. During World War I he worked for a while at the Cramp Ship Yards in Philadelphia.

From 1920 until his death Keith was associated with Metcalf & Eddy, except for the year 1938 when he was with the late Frank A. Barbour, Past President of this Association. During his association with Metcalf & Eddy he rose from Assistant Engineer to Project Engineer and was admitted as partner in January, 1950. In 1941-43 he was Chief Engineer of the New York office of Metcalf & Eddy during the design and construction of the Bermuda Air Base.

In general, Keith's professional activities were devoted to water works and hydraulics. Some of the New England communities upon whose water-supply problems he had been engaged were Brunswick, Concord (Mass.), Duxbury, Falmouth, Groton (Conn.), Needham, Pembroke (N. H.), Plymouth (Mass.), St. Johnsbury, Westborough, Weston and Woburn.

Keith was a member of the American Society of Civil Engineers and the Boston Society of Civil Engineers. He was a Director of the New England Water Works Association and had contributed a number of articles on water supply and hydraulics to its Journal.

Scott Keith was an able, conscientious and extremely meticulous engineer. His computations and notes were models of neatness and

accuracy. To every assignment he gave his best with thoroughness and efficiency.

Besides his wife, Grace F. (Cunningham), to whom he was married in 1921, he leaves three daughters, Mrs. Irvin C. Bailey of Duxbury, Marjorie and Diana; two sons, Alan and William F.; and a sister, Mrs. Burton Shepherd of Kingston.

It is hard for one with whom he had been closely associated for over thirty years to express in cold print an appreciation of Scott Keith. Personal relations cannot be expressed in words. Perhaps loyalty, integrity and sincerity best express Keith's character and personality. Those of us who had long been associated with him will miss his congenial presence and the satisfaction of working with a man of his high character. His death at an early age is a loss to his friends, to his family, and to the water-works profession.

E. SHERMAN CHASE

PROCEEDINGS

April 1953 Meeting

The Hedges, New Britain, Conn.

Thursday, April 16, 1953

Despite adverse weather conditions, members of the New England Water Works Association and their guests met at the well system of the city of New Britain, in Bristol, Conn., and inspected the works and filtration installation there. They then proceeded across the city in a police-escorted motorcade to the 10-mgd Morse-type rapid-sand filtration plant of the city of New Britain. There the use and operation of the plant, as well as fluoridation equipment, were fully explained and observed.

After luncheon at "The Hedges", President Stanley M. Dore called upon the Hon. John L. Sullivan, Mayor of New Britain, who gave the group a very warm welcome and extended a cordial invitation to return to that city whenever possible.

A paper, "New Britain Filtration Plant," was read by I. Laird Newell, Chief Chemist, Newlands Sanitary Laboratory, Hartford, Conn.

A paper, "The Development of a Large Well Supply," was read by Frederick B. Silliman, Assistant to the President, The Bridgeport Hydraulic Co., Bridgeport, Conn.

During the reading of the technical papers, the ladies who attended went by bus to the Connecticut Teachers' College, where a most enjoyable afternoon was spent.

May 1953 Meeting

Stanley Park Pavilion, Westfield, Mass.

Thursday, May 21, 1953

Members of the New England Water Works Association and their guests assembled at the West Parish Filters of the Springfield Water Works and spent the better part of the morning inspecting the additions to filters and laboratory facilities. After that inspection, many took the opportunity to go on a tour of inspection of the power plant and the Cobble Mt. Reservoir.

Luncheon was served in the beautiful pavilion at Stanley Park in Westfield, after which President Stanley M. Dore called upon the Hon. Daniel B. Brunton, Mayor of Springfield, and the Hon. Richard E. Fuller, Mayor of Westfield, both of whom accorded the gathering a most cordial welcome.

A paper, "New Additions to West Parish Filters," was read by Peter C. Karalekas, Chief Water Engineer, Municipal Water Works, Springfield, Mass.

A paper, "Quality Control of the Water in the Springfield System," was read by John P. Lynch, Chemist and Bacteriologist, Municipal Water Works, Springfield, Mass.

UDC 621.774.1

ASA A21.6-1953
(AWWA C106-53)

American Standard Specifications

for

CAST IRON PIPE CENTRIFUGALLY CAST IN METAL MOLDS, FOR WATER OR OTHER LIQUIDS

PUBLISHED BY AMERICAN WATER WORKS ASSOCIATION, INC.

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AMERICAN WATER WORKS ASSOCIATION
NEW ENGLAND WATER WORKS ASSOCIATION

Approved by American Standards Association Jan. 13, 1953

AMERICAN WATER WORKS ASSOCIATION
Incorporated
521 Fifth Avenue, New York 17, N.Y.

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Table 6.2—Standard Thicknesses, Diameters and Weights of Pipe Centrifugally Cast in Metal Molds.

Table 6.3—Standard Thicknesses and Weights of Pipe Centrifugally Cast in Metal Molds (Classes 50–350, laid without blocks, on flat-bottom trench, with tamped backfill, under 5 ft of cover).

Table 6.4—Standard Thicknesses of Pipe Centrifugally Cast in Metal Molds (for laying conditions A, B, C and D, pressures 50–350, and 3½, 5 and 8 ft of cover.

NOTE 1—Tables showing additional thicknesses required for greater depths of cover and other conditions of laying will be found in ASA A21.1.

NOTE 2—Users of these tables are cautioned to select fittings having proper socket dimensions and thicknesses suited to the pressures. Pipe specified in these tables have outside diameters which will chamber correctly with existing standards for pipe and fittings.

Users of this document should make reference to "American Recommended Practice Manual for the Computation of Strength and Thickness of Cast Iron Pipe" (ASA A21.1) for complete information concerning the conditions which various thicknesses of pipe are designed to meet. The foreword of the Manual also contains a statement regarding the history of the specifications and references to other related documents.

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ASA A21.6-1953
(AWWA C106-53)

American Standard Specifications for

Cast Iron Pipe Centrifugally Cast in Metal Molds, for Water or Other Liquids

This specification covers cast iron pipe centrifugally cast in metal molds.

Sec. 6-1—Definitions

Purchaser. Wherever the word "purchaser" is used herein, it shall be understood to mean the actual purchaser of the pipe or his authorized agents acting within the scope of the duties entrusted to them.

Heat. A heat is a period during which a cupola or furnace is operated continuously.

Run. A run is a period of one or more shifts during which a shop is operated continuously.

Mixture of Iron. Mixture of iron is a combination of pig iron, scrap, coke and other raw materials charged to a cupola or furnace to give a desired composition of iron; or a combination of molten iron from one or more sources, made in a forehearth or ladle to give a desired composition of iron.

Source of Iron. A source of iron is a cupola, furnace or forehearth from which iron is delivered to a transfer or pouring ladle.

Forehearth. A forehearth is a refractory-lined receptacle for the temporary storage of molten iron from one or more cupolas or furnaces.

Sec. 6-2—Description of Pipe

The pipe shall be made with bell and spigot ends, plain ends or such other type of ends as may be agreed upon at the time of purchase. Pipe with bell-and-spigot ends shall conform to the dimensions and weights shown in the tables given in this document. Pipe with other types of ends shall comply with the dimensions agreed upon, but in all other respects shall fulfill the specifications hereinafter given. Pipe shall be straight and shall be true circles in section, with the inner and outer surfaces concentric. Pipe shall be cast at least 12 ft in nominal laying length. This type of pipe is commonly made at present (1952) in 12- and 18-ft lengths.

Sec. 6-3—Casting of Pipe

The pipe shall be centrifugally cast in metal molds, and after withdrawal from the molds pipe shall be heat-treated to meet the requirements of this specification.

Sec. 6-4—Quality of Iron

6-4.1. All pipe shall be made of cast iron of good quality, and of such

character and so adapted in chemical composition to the thickness of the pipe to be cast, that the iron in the pipe shall be strong, tough, resilient, of even grain and soft enough for satisfactory drilling and cutting, and it shall comply with the physical specifications given in Sec. 6–17 and 6–18. The metal shall be remelted in a cupola or other suitable furnace.

6–4.2. The iron in the pipe shall not contain more than 0.90 per cent of phosphorus nor more than 0.12 per cent of sulphur. Samples for chemical analyses shall be taken by drilling completely through from skin to skin either acceptance test specimens or specimens cast for this purpose, but not to exceed three specimens per heat of approximately eight hours. In case of dispute, analyses will be determined on samples taken from the pipe in question.

Sec. 6–5—Quality of Castings

The pipe shall be smooth, free from scales, lumps, blisters, sand holes, laps and defects of every nature which unfit them for the use for which they are intended. No plugging, filling, burning-in or welding will be allowed except as permitted by the purchaser.

Sec. 6–6—Foundry Records

A record of the results of the following tests shall be made and retained for at least one year. Upon request such record will be available to the purchaser at the foundry. If written transcripts of the results of any of these tests are desired this fact shall be noted in the order for pipe, naming the tests of which transcripts are desired. The methods of testing and the dimensions of all test specimens are given in the Appendix.

6–6.1. *Chemical analyses.* Chemical analyses of each iron mixture used directly in the pouring of pipe, obtained as in Sec. 6–4.2, shall be made for silicon, sulphur, manganese, phosphorus and total carbon during the first hour and at intervals not to exceed three hours throughout the heat. If pipe are poured directly from the cupola, chemical analyses shall be made of iron from the first and from the last ladle. If the mixture is changed one or more times during a heat in order to produce a different iron, the time of taking samples shall be varied in such a way as to obtain representative tests of the iron at least at the beginning and end of each period during which the iron is intended to be constant in quality.

6–6.2. *Pouring temperatures.* The pouring temperature of the iron shall be taken at the casting ladle for each size of pipe at least once each hour.

6–6.3. *Hardness tests.* See Sec. 6–17.2 and Appendix Sec. 6–A1—Talbot Strip Tests.

6–6.4. *Talbot strip tests.* See Sec. 6–17.1.

6–6.5. *Periodic ring, strip and full-length bursting tests.* See Sec. 6–17 and 6–18.

Sec. 6–7—Marking Pipe

Each pipe shall have the weight and class designation conspicuously painted on it. In addition, each bell-and-spigot pipe shall have distinctly cast or stamped on the face of the bell the manufacturer's mark and the year in which the pipe was cast. When specified by the purchaser, the manufacturer's mark, the year in which the pipe was cast and initials not exceeding four in number shall be distinctly cast on the face of the bell. The size of

letters and figures is to be as large as practicable. Pipe with ends other than bell and spigot are to be marked as agreed upon at the time of purchase.

Sec. 6–8—Inspection by Purchaser

6–8.1. *Power of purchaser to inspect.* The purchaser shall have free access at all times to all parts of any manufacturing plant which concern the manufacture of articles to be made for him. He may inspect the material, pattern work, molding, casting, heat-treating, coating and lining of the pipe. The forms, sizes, uniformity and conditions of all pipe herein referred to shall be subject to his inspection and approval, and he may reject, without subjection to hydrostatic test, any pipe which is not in conformity with the specifications or drawings. Any pipe rejected shall be so marked and any marks pertaining to the purchaser shall be chipped or erased from such pipe.

6–8.2. *Manufacturer to furnish men and materials.* The manufacturer shall provide tools, testing equipment, materials, labor and facilities necessary for the required testing, inspection and weighing of the pipe at the foundry.

6–8.3. *Report of purchaser's inspection.* The purchaser shall make written report daily to the foundry office of all pipe rejected with the causes for rejection.

Sec. 6–9—Inspection and Certification by Manufacturer

Should the purchaser have no inspector at the works, the manufacturer shall, if required by the purchaser, furnish a sworn statement that the inspection and all of the tests have been made and met as specified. If written transcripts of any of these test results are required, including chemical tests if desired, a request specifying the tests of which transcripts are desired shall accompany the order.

Sec. 6–10—Pipe to Be Delivered Sound

All the pipe shall be delivered in all respects sound and in conformity with these specifications. The inspection shall not relieve the manufacturer of any of his obligations in this respect, and any defective pipe which may have passed the purchaser at the works or elsewhere shall be at all times liable to rejection when discovered, until the final completion and adjustment of the contract; provided, however, that the manufacturer shall not be held liable for pipe found to be damaged after they have been accepted at the agreed point of delivery, unless there shall be unmistakable evidence that the casting was originally defective or damaged before acceptance. Care shall be taken in handling the pipe not to injure the coating or lining, and no pipe or other material of any kind shall be placed in the pipe during transportation or at any other time after they have received the coating or lining.

Sec. 6–11—Cut Pipe

Defective spigot ends on pipe may be cut off in a manner which will produce a square end. Not more than 10 per cent of the total number of pipe of each size of a given order may be shipped as cut pipe. Such cut pipe when cut from 12-ft lengths shall have a nominal laying length of not less than 11 ft; pipe originally of 16-ft or greater length shall not be cut more than 2 ft.

character and so adapted in chemical composition to the thickness of the pipe to be cast, that the iron in the pipe shall be strong, tough, resilient, of even grain and soft enough for satisfactory drilling and cutting, and it shall comply with the physical specifications given in Sec. 6–17 and 6–18. The metal shall be remelted in a cupola or other suitable furnace.

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6–6.2. *Pouring temperatures.* The pouring temperature of the iron shall be taken at the casting ladle for each size of pipe at least once each hour.

6–6.3. *Hardness tests.* See Sec. 6–17.2 and Appendix Sec. 6–A1—Talbot Strip Tests.

6–6.4. *Talbot strip tests.* See Sec. 6–17.1.

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Defective spigot ends on pipe may be cut off in a manner which will produce a square end. Not more than 10 per cent of the total number of pipe of each size of a given order may be shipped as cut pipe. Such cut pipe when cut from 12-ft lengths shall have a nominal laying length of not less than 11 ft; pipe originally of 16-ft or greater length shall not be cut more than 2 ft.

Sec. 6–12—Tolerances or Maximum Permitted Variations

6–12.1. *Pipe and socket diameters.* Outside diameters of pipe barrels and spigot ends, and inside diameters of sockets, shall be kept as nearly as practicable to the specified dimensions. The inside diameters of the sockets and the outside diameters of the spigot ends shall be tested with circular gages. Tolerances or maximum permitted variations from standard dimensions are listed below:

Nom. Pipe Diam. *in.*	Tolerances *in.*
3–12	±0.06
14–24	±0.08

6–12.2. *Thickness.* The minus tolerances from standard thickness of pipe and dimensions *a*, *b*, *c* and *d* of the bell are as follows:

Nom. Pipe Diam. *in.*	Minus Tolerance *in.*
3– 8	0.05
10–12	0.06
14–24	0.08

Note: In pipe barrel thickness, tolerances 0.02 in. greater than those listed above shall be permissible over areas not exceeding 8 in. in length in any direction.

6–12.3. *Weight.* The weight of no single pipe shall be less than the nominal tabulated weight by more than 5 per cent for pipe 12 in. or smaller in diameter, nor by more than 4 per cent for pipe larger than 12 in. in diameter. The total weight of any order of 25 tons or more shall not be more than 2 per cent under the total nominal weight. The total excess weight to be paid for on orders of 25 tons or more shall not exceed 2 per cent of the nominal weight and on orders of less than 25 tons shall not exceed 5 per cent of the nominal weight. An order is hereby defined as including all the pipe ordered under the terms of a specific contract or purchase order or a single order placed under the terms of a standing contract. Unless otherwise specified in the contract, a ton shall be 2,000 lb avoirdupois.

Sec. 6–13—Cleaning and Inspecting

All pipe shall have fins and other roughnesses chipped or ground off and shall be thoroughly cleaned, checked as to dimensions and also subjected to a careful inspection and a rolling test, before being coated or lined.

Sec. 6–14—Hydrostatic Test

Each pipe shall be subjected to a hydrostatic proof test. This test may be made either before or after a hot or cold bituminous dip or paint has been applied but shall be made before the cement mortar lining or any other special lining has been applied to pipe for which such lining is specified.

The pipe shall be under the test pressure for at least one-half minute. Any pipe showing defects by leaking, sweating or otherwise shall be rejected. The test pressures shall be in accordance with the table appearing on page 5.

Sec. 6–15—Weighing

Each length of pipe shall be weighed and the weight plainly marked on the outside or inside of the bell or spigot end. Pipe shall be weighed before the application of any lining or coating other than hot or cold bituminous dip or paint.

Table of Hydrostatic Test Pressures

Nom. Pipe Diam. *in.*	Nom. Barrel Thickness *in.*	Test Pressure *psi*
3–12	all thicknesses	500
14	0.57 and less	400
14	0.58 and over	500
16	0.60 and less	400
16	0.61 and over	500
18	0.65 and less	400
18	0.66 and over	500
20	0.70 and less	400
20	0.71 and over	500
24	0.75 and less	400
24	0.76 and over	500

Sec. 6–16—Linings and Exterior Coatings

Any particular lining or coating which is to be applied to the pipe shall be specified in the agreement made at the time of purchase. Separate specifications for cement-mortar lining (ASA A21.4, also known as AWWA C104) have been provided in connection with specifications for pipe.

No pipe for water works service shall be furnished without protective coating unless specifically ordered by the purchaser.

Sec. 6–17—Acceptance Tests for Physical Properties

The standard acceptance tests for the physical characteristics of the pipe shall be as follows:

Sec. 6–17.1—Talbot Strip Tests

Talbot strip tests shall be used to determine the acceptability of 3-in. to 24-in. pipe for modulus of rupture and secant modulus of elasticity.

17.1.1. *Sampling.* For sampling, every run shall be divided into periods of approximately three hours each, and at least one sample shall be taken during each three-hour period. The sample for the first period of the run shall be taken during the first hour or, if casting is direct from the cupola, from the first ladle. Samples shall be taken so that each size of pipe cast for two hours or longer during the run and each mixture or source of iron used for two hours or longer during the run shall be fairly represented.

17.1.2. *Method of testing.* The method of testing Talbot strips is given in Sec. 6–A1 of the Appendix.

17.1.3. *Acceptance values.* The acceptance values for tests on Talbot strips from 3-in. to 24-in. pipe shall be as follows:

Modulus of rupture: 40,000 psi minimum

Secant modulus of elasticity: 12,000,000 psi maximum

If the modulus of elasticity exceeds 12,000,000, the modulus of rupture shall exceed 40,000 in at least the same proportion.

Sec. 6–17.2—Hardness Tests

On the outside of each pipe a hardness determination shall be made with a portable instrument. The Rockwell hardness number or its equivalent shall not exceed B–95, using a ball having a diameter of 1.59 mm ($\frac{1}{16}$ in.) and a weight of 100 kg (220.5 lb). Any harder pipe may be re-heat-treated to meet this requirement. For the purpose of the foundry records (Sec. 6–6.3), hardness tests shall be made also on Talbot strips as noted in the Appendix under "Talbot Strip Tests" —viz., a Rockwell hardness test at three well distributed points each on the outside of the pipe and on one machined face shall be made and recorded.

Sec. 6–18—Periodic Ring Tests and Full-Length Bursting Tests

The manufacturer shall periodically make such bursting tests and ring tests in conjunction with strip tests that he can certify the design values of the modulus of rupture (40,000 psi) and the tensile strength of the iron in the pipe (18,000 psi). These tests shall be made in accordance with dimensions and methods given in the Appendix.

Pipe for these periodic ring and bursting tests shall be so selected that they will be representative of the sizes and various thicknesses of each size cast. Ring tests shall not be made on 3-in. and 4-in. pipe.

Tests of Talbot strips cut from the ring and hardness tests as provided in the Appendix shall be made in conjunction with ring and bursting tests. At least three Talbot strips shall be tested from each burst pipe and one of these strips shall come from the ring. For pipe for which rings less than 10½ in. long are used, the Talbot strip shall come from parts other than the ring.

Tests and records shall include the modulus of rupture of each strip and ring, the modulus of elasticity of each strip and of each ring 12 in. and larger, and a hardness test on all strips.

At the purchaser's request, the manufacturer shall furnish a written transcript of ring and bursting tests and tests on Talbot strips made in connection therewith for a period not exceeding one year and for such sizes as requested.

Sec. 6–19—Additional Tests Required by Purchaser

If more or other tests than those provided in these specifications are required by the purchaser, such tests shall be specified in the invitation for bids.

Sec. 6–20—Defective Specimens and Retests

If any test specimen shows defective machining or lack of continuity of metal, it may be discarded and replaced by another specimen. If any sound test specimen fails to meet the specified requirements, the purchaser may permit a retest on two additional sound specimens from pipe cast in the same period as the specimen which failed; both of the additional specimens shall meet the prescribed tests to be acceptable.

Sec. 6–21—Rejection of Pipe

If any routine chemical analysis fails to meet the chemical requirements of Sec. 6–4.2, or if any acceptance test fails to meet the requirements of Sec. 6–17.1.3, 6–17.2 and 6–20, the pipe cast in the period shall be rejected except as subject to the provisions of Sec. 6–22.

Sec. 6–22—Limiting Rejection

The manufacturer may limit the amount of rejection by making similar additional tests of pipe of the same size as that rejected until the rejected lot is bracketed in order of manufacture by two acceptable tests. If a period is rejected, the acceptability of pipe of different sizes from that rejected may be established by making the routine acceptance tests for these sizes.

Appendix *

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Sec. 6-A1—Talbot Strip Tests

Sec. 6-A2—Ring Tests

Sec. 6-A3—Full-Length Bursting Tests

Sec. 6-A4—Deflection Measurements

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Table 6.2—Standard Thicknesses, Diameters and Weights of Pipe Centrifugally Cast in Metal Molds.

Table 6.3—Standard Thicknesses and Weights of Pipe Centrifugally Cast in Metal Molds.

Table 6.4—Standard Thicknesses of Pipe Centrifugally Cast in Metal Molds.

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* This Appendix is a part of ASA A21.6—American Standard Specifications for Cast Iron Pipe Centrifugally Cast in Metal Molds, for Water or Other Liquids.

† Data on thicknesses required for greater depths of cover and conditions of laying other than those assumed in the following tables will be found in Appendix B of ASA A21.1—American Recommended Practice Manual for the Computation of Strength and Thickness of Cast Iron Pipe.

Users of the following tables are cautioned to select fittings having proper socket dimensions and thicknesses suited to the pressures. Pipe specified in these tables have outside diameters which will chamber correctly with existing standards for pipe and fittings.

Sec. 6–A1—Talbot Strip Tests

Talbot strips (Fig. 6.1) shall be machined longitudinally from each pipe specimen selected for testing by this method. These Talbot strips may be cut from a part of the ring little stressed in the ring test—i.e., near one of the elements marked *a* in the illustration of the ring test (Fig. 6.2). The strips in any case will be in cross section as indicated in Fig. 6.1—i.e., will have for their width the thickness of the pipe and for their depth 0.50 in. Their length shall be at least 10½ in. These strips shall be tested as beams on supports 10 in. apart with loads applied perpendicularly to the machined faces at two points 3⅓ in. from the supports. The breaking load and the deflection shall be observed and recorded. For

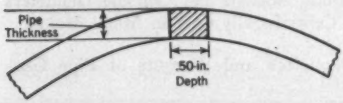

FIG. 6.1. Position From Which Talbot Strip Is Cut

purposes of Sec. 6–6.3—Foundry Records, a Rockwell hardness test at three well distributed points each on the outside of the pipe and on one machined face shall be made and recorded.

The strip shall be accurately calipered at the point of rupture and the modulus of rupture, R, shall be calculated by the usual beam formula, which for this case reduces to the expression:

$$R = \frac{10W}{td^2}$$

The secant modulus of elasticity, E_s, in pounds per square inch, shall be computed by the formula:

$$E_s = \frac{21.3R}{dy}$$

In the above formulas, R is the modulus of rupture (psi), E_s is the secant modulus of elasticity (psi), W is the breaking load (lb), d is the depth (in.) of the strip (intended to be 0.50 in.), t is the width (in.) of the strip (pipe thickness) and y is the deflection (in.) of the strip at the center at breaking load.

Sec. 6–A2—Ring Tests

The maximum length of any ring shall not exceed 12 in.; for pipe 14 in. and larger, the minimum length shall be 10½ in.; for pipe 12 in. and smaller, the minimum length shall be one-half the nominal diameter of the pipe. Each ring shall be tested by the three-edge

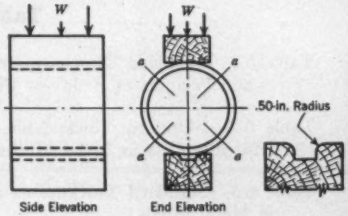

FIG. 6.2. Assembly for Ring Test

bearing method as indicated in Fig. 6.2. The lower bearing for the ring shall consist of two strips with vertical sides having their interior top edges rounded to a radius of approximately ½ in. The strips shall be of hard wood or of metal. If of metal, a piece of fabric or leather approximately $\frac{3}{16}$ in. thick shall be laid over them. They shall be straight and shall be securely fastened to a rigid block with their interior vertical faces the following distances apart:

Nom. Pipe Diam. *in.*	Bearing Strip Spacing *in.*
3–12	½
14–24	1

The upper bearing shall be an oak block, straight and true from end to end. The upper and lower bearings shall extend the full length of the ring. The ring shall be placed symmetrically between the two bearings, and the center of application of the load shall be so placed that the vertical deformation at the two ends of the ring shall be approximately equal. If the ring is not uniform in thickness, it shall be so placed that the thick and thin portions are near the ends of the horizontal diameter.

A record of the breaking load and the vertical deformation of each ring tested shall be made. The modulus of rupture and modulus of elasticity are computed from the formulas:

$$R = 0.954\frac{W(d+t)}{bt^2}$$

$$E = \frac{0.225W(d+t)^3}{bt^3y} = \frac{0.236R(d+t)^2}{ty}$$

in which R is the modulus of rupture (psi), W is the breaking load (lb), d is the average inside diameter (in.) of the ring, t is the average thickness (in.) of metal along the line of fracture, b is the length (in.) of the ring, E is the modulus of elasticity (psi) and y is the vertical deformation (in.) of the ring at the center.

Sec. 6–A3—Full-Length Bursting Tests

The bursting tensile strength shall be determined by testing full-length pipe (less the amount cut off for ring and strip test specimens) to destruction by hydraulic pressure. Bells may be removed to facilitate testing. A suitable means for holding the end thrust shall be used which will not subject the pipe to endwise tension or compression, or other parasitic stresses. A calibrated pressure gage shall be used for determining the bursting pressure. This gage shall be connected to the interior of the test pipe by a separate connection from that which supplies water for the test. The unit tensile strength in bursting shall be obtained by the use of the formula:

$$S = \frac{Pd}{2t}$$

in which S is the bursting tensile strength (psi) of the iron, P is the internal pressure (psi) at bursting, d is the average inside diameter (in.) of the pipe and t is the minimum average thickness (in.) of the pipe along the principal line of break.

Measurements of thickness shall be taken along the principal line of break at 1-ft intervals.

The minimum average thickness along the principal line of break shall be obtained by averaging the measurements at the thinnest section at a weight of two and at the adjacent sections on each side at a weight of one each; or, if the thinnest section is at the end of the break, by averaging this thinnest-section measurement at a weight of two and the measurements of the adjacent section and the next section at a weight of one each.

Sec. 6–A4—Deflection Measurements

All deflection measurements required by these specifications shall be that of the specimen and shall not include any compression of the supports or loading blocks, or backlash or distortion of the testing machine.

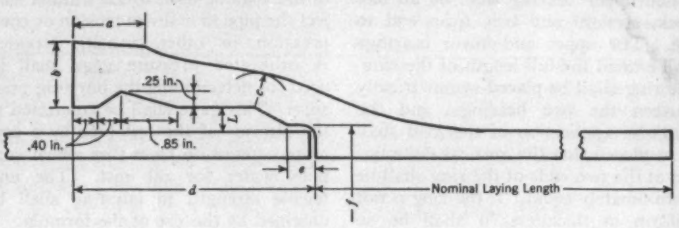

TABLE 6.1

STANDARD DIMENSIONS OF BELLS, SOCKETS AND OUTSIDE DIAMETERS—AND WEIGHTS OF BELLS—OF PIPE CENTRIFUGALLY CAST IN METAL MOLDS

Nom. Diam.	Pipe Thickness		Pipe Outside Diam.	Dimensions of Bells								Bell Weight
				Socket Diam.	Joint Thickness L	Socket Depth d	Centering Shoulder		a	b	c	
	From	To					Depth e	Inside Diam. f				
	in.											lb
3	0.32	0.38	3.96	4.76	0.40	3.30	0.30	4.10	0.88	1.02	0.41	11
4	0.35	0.44	4.80	5.60	0.40	3.30	0.30	4.94	1.00	1.06	0.47	14
	0.35	0.44	5.00	5.80	0.40	3.30	0.30	5.14	1.00	1.06	0.47	15
6	0.38	0.48	6.90	7.70	0.40	3.88	0.38	7.06	1.13	1.10	0.55	25
	0.38	0.52	7.10	7.90	0.40	3.88	0.38	7.26	1.13	1.10	0.55	26
8	0.41	0.56	9.05	9.85	0.40	4.38	0.38	9.21	1.13	1.28	0.64	41
	0.41	0.60	9.30	10.10	0.40	4.38	0.38	9.46	1.13	1.28	0.64	42
10	0.44	0.60	11.10	11.90	0.40	4.38	0.38	11.28	1.13	1.38	0.69	54
	0.44	0.65	11.40	12.20	0.40	4.38	0.38	11.58	1.13	1.38	0.69	56
12	0.48	0.65	13.20	14.00	0.40	4.38	0.38	13.38	1.13	1.42	0.71	66
	0.48	0.60	13.50	14.30	0.40	4.38	0.38	13.68	1.13	1.42	0.71	67
	0.65	0.76	13.50	14.30	0.40	4.38	0.38	13.68	1.13	1.62	0.81	78
14	0.48	0.69	15.30	16.10	0.40	4.50	0.50	15.52	1.25	1.46	0.73	78
	0.48	0.64	15.65	16.45	0.40	4.50	0.50	15.87	1.25	1.46	0.73	80
	0.69	0.81	15.65	16.45	0.40	4.50	0.50	15.87	1.25	1.76	0.88	101
16	0.50	0.73	17.40	18.40	0.50	4.50	0.50	17.62	1.25	1.54	0.77	96
	0.50	0.68	17.80	18.80	0.50	4.50	0.50	18.02	1.25	1.54	0.77	98
	0.73	0.85	17.80	18.80	0.50	4.50	0.50	18.02	1.25	1.86	0.93	121
18	0.54	0.79	19.50	20.50	0.50	4.50	0.50	19.72	1.25	1.64	0.82	114
	0.54	0.73	19.92	20.92	0.50	4.50	0.50	20.14	1.25	1.64	0.82	116
	0.79	0.92	19.92	20.92	0.50	4.50	0.50	20.14	1.25	1.98	0.99	145
20	0.57	0.84	21.60	22.60	0.50	4.50	0.50	21.82	1.25	1.74	0.87	133
	0.57	0.78	22.06	23.06	0.50	4.50	0.50	22.28	1.25	1.74	0.87	136
	0.84	0.98	22.06	23.06	0.50	4.50	0.50	22.28	1.25	2.10	1.05	171
24	0.63	0.92	25.80	26.80	0.50	4.50	0.50	26.02	1.25	1.94	0.97	179
	0.63	0.85	26.32	27.32	0.50	4.50	0.50	26.54	1.25	1.94	0.97	182
	0.92	1.07	26.32	27.32	0.50	4.50	0.50	26.54	1.25	2.36	1.18	229

TABLE 6.2

STANDARD THICKNESSES, DIAMETERS AND WEIGHTS OF PIPE CENTRIFUGALLY CAST IN METAL MOLDS

Nom. Diam. in.	Thickness Class	Thickness	Outside Diam.	Inside Diam.	Barrel Weight Per Foot	Bell Weight	Weight Based on 12-ft Laying Length		Weight Based on 18-ft Laying Length	
							Per Length*	Avg. Per Foot†	Per Length*	Avg. Per Foot†
		in.			lb					
3	22	0.32	3.96	3.32	11.4	11	150	12.5	215	12.0
	23	0.35	3.96	3.26	12.4	11	160	13.5	235	13.0
	24	0.38	3.96	3.20	13.3	11	170	14.3	250	13.9
4	22	0.35	4.80	4.10	15.3	14	200	16.6	290	16.1
	23	0.38	4.80	4.04	16.5	14	210	17.7	310	17.3
	24	0.41	4.80	3.98	17.6	14	225	18.8	330	18.4
	25	0.44	4.80	3.92	18.8	14	240	20.0	350	19.5
	22	0.35	5.00	4.30	16.0	15	205	17.2	305	16.9
	23	0.38	5.00	4.24	17.2	15	220	18.5	325	18.0
	24	0.41	5.00	4.18	18.4	15	235	19.7	345	19.2
	25	0.44	5.00	4.12	19.7	15	250	21.0	370	20.5
6	22	0.38	6.90	6.14	24.3	25	315	26.4	460	25.6
	23	0.41	6.90	6.08	26.1	25	340	28.2	495	27.5
	24	0.44	6.90	6.02	27.9	25	360	30.0	525	29.3
	25	0.48	6.90	5.94	30.2	25	385	32.2	570	31.7
	22	0.38	7.10	6.34	25.0	26	325	27.2	475	26.4
	23	0.41	7.10	6.28	26.9	26	350	29.1	510	28.2
	24	0.44	7.10	6.22	28.7	26	370	30.9	545	30.2
	25	0.48	7.10	6.14	31.1	26	400	33.3	585	32.5
	26	0.52	7.10	6.06	33.5	26	430	35.7	630	34.9
8	22	0.41	9.05	8.23	34.7	41	455	38.1	665	36.9
	23	0.44	9.05	8.17	37.1	41	485	40.5	710	39.4
	24	0.48	9.05	8.09	40.3	41	525	43.7	765	42.6
	25	0.52	9.05	8.01	43.5	41	565	46.9	825	45.8
	26	0.56	9.05	7.93	46.6	41	600	50.0	880	48.9
	22	0.41	9.30	8.48	35.7	42	470	39.2	685	38.0
	23	0.44	9.30	8.42	38.2	42	500	41.7	730	40.5
	24	0.48	9.30	8.34	41.5	42	540	45.0	790	43.8
	25	0.52	9.30	8.26	44.8	42	580	48.3	850	47.1
	26	0.56	9.30	8.18	48.0	42	620	51.5	905	50.3
	27	0.60	9.30	8.10	51.2	42	655	54.7	965	53.5
10	22	0.44	11.10	10.22	46.0	54	605	50.5	880	49.0
	23	0.48	11.10	10.14	50.0	54	655	54.5	955	53.0
	24	0.52	11.10	10.06	53.9	54	700	58.4	1025	56.9
	25	0.56	11.10	9.98	57.9	54	750	62.4	1095	60.9
	26	0.60	11.10	9.90	61.8	54	795	66.3	1165	64.8
	22	0.44	11.40	10.52	47.3	56	625	52.0	905	50.4
	23	0.48	11.40	10.44	51.4	56	675	56.1	980	54.5
	24	0.52	11.40	10.36	55.5	56	720	60.2	1055	58.6
	25	0.56	11.40	10.28	59.5	56	770	64.2	1125	62.6
	26	0.60	11.40	10.20	63.5	56	820	68.2	1200	66.6
	27	0.65	11.40	10.10	68.5	56	880	73.2	1290	71.6
12	22	0.48	13.20	12.24	59.8	66	785	65.3	1140	63.4
	23	0.52	13.20	12.16	64.6	66	840	70.1	1230	68.3
	24	0.56	13.20	12.08	69.4	66	900	74.9	1315	73.1
	25	0.60	13.20	12.00	74.1	66	955	79.6	1400	77.8
	26	0.65	13.20	11.90	80.0	66	1025	85.5	1505	83.7
	22	0.48	13.50	12.54	61.3	67	805	66.9	1170	65.0
	23	0.52	13.50	12.46	66.2	67	860	71.8	1260	69.9
	24	0.56	13.50	12.38	71.0	67	920	76.6	1345	74.8
	25	0.60	13.50	12.30	75.9	67	980	81.5	1435	79.7
	26	0.65	13.50	12.20	81.9	78	1060	88.4	1550	86.2
	27	0.70	13.50	12.10	87.8	78	1130	94.3	1660	92.1
	28	0.76	13.50	11.98	94.9	78	1215	101.4	1785	99.2
14	21	0.48	15.30	14.34	69.7	78	915	76.2	1335	74.1
	22	0.51	15.30	14.28	73.9	78	965	80.4	1410	78.2
	23	0.55	15.30	14.20	79.5	78	1030	86.0	1510	83.8
	24	0.59	15.30	14.12	85.1	78	1100	91.6	1610	89.5
	25	0.64	15.30	14.02	92.0	78	1180	98.5	1735	96.5
	26	0.69	15.30	13.92	98.8	78	1265	105.3	1855	103.1

* Including bell. Calculated weight of pipe rounded off to nearest 5 lb.
† Average weight per foot based on calculated weight of pipe before rounding.

TABLE 6.2 (contd.)

STANDARD THICKNESSES, DIAMETERS AND WEIGHTS OF PIPE CENTRIFUGALLY CAST IN METAL MOLDS

Nom. Diam. in.	Thickness Class	Thickness	Outside Diam.	Inside Diam.	Barrel Weight Per Foot	Bell Weight	Weight Based on 12-ft Laying Length		Weight Based on 18-ft Laying Length	
							Per Length*	Avg. Per Foot†	Per Length*	Avg. Per Foot†
		in.			lb					
14	21	0.48	15.65	14.69	71.4	80	935	78.1	1365	75.8
	22	0.51	15.65	14.63	75.7	80	990	82.4	1445	80.2
	23	0.55	15.65	14.55	81.4	80	1055	88.1	1545	85.8
	24	0.59	15.65	14.47	87.1	80	1125	93.8	1650	91.6
	25	0.64	15.65	14.37	94.2	80	1210	100.9	1775	98.7
	26	0.69	15.65	14.27	101.2	101	1315	109.6	1925	106.9
	27	0.75	15.65	14.15	109.5	101	1415	117.9	2070	115.1
	28	0.81	15.65	14.03	117.8	101	1515	126.2	2220	123.4
16	21	0.50	17.40	16.40	82.8	96	1090	90.8	1585	88.1
	22	0.54	17.40	16.32	89.2	96	1165	97.2	1700	94.5
	23	0.58	17.40	16.24	95.6	96	1245	103.6	1815	100.9
	24	0.63	17.40	16.14	103.6	96	1340	111.6	1960	109.0
	25	0.68	17.40	16.04	111.4	96	1435	119.4	2100	116.8
	26	0.73	17.40	15.94	119.3	96	1530	127.3	2245	124.8
	21	0.50	17.80	16.80	84.8	98	1115	93.0	1625	90.2
	22	0.54	17.80	16.72	91.4	98	1195	99.6	1745	96.9
	23	0.58	17.80	16.64	97.9	98	1275	106.1	1860	103.3
	24	0.63	17.80	16.54	106.0	98	1370	114.2	2005	111.5
	25	0.68	17.80	16.44	114.1	98	1465	122.2	2150	119.5
	26	0.73	17.80	16.34	122.1	121	1585	132.2	2320	128.8
	27	0.79	17.80	16.22	131.7	121	1700	141.8	2490	138.4
	28	0.85	17.80	16.10	141.2	121	1815	151.3	2665	148.0
18	21	0.54	19.50	18.42	100.4	114	1320	109.9	1920	106.7
	22	0.58	19.50	18.34	107.6	114	1405	117.1	2050	113.9
	23	0.63	19.50	18.24	116.5	114	1510	126.0	2210	122.8
	24	0.68	19.50	18.14	125.4	114	1620	134.9	2370	131.8
	25	0.73	19.50	18.04	134.3	114	1725	143.8	2530	140.6
	26	0.79	19.50	17.92	144.9	114	1855	154.4	2720	151.2
	21	0.54	19.92	18.84	102.6	116	1345	112.2	1965	109.1
	22	0.58	19.92	18.76	109.9	116	1435	119.6	2095	116.3
	23	0.63	19.92	18.66	119.1	116	1545	128.8	2260	125.5
	24	0.68	19.92	18.56	128.2	116	1655	137.9	2425	134.8
	25	0.73	19.92	18.46	137.3	116	1765	147.0	2585	143.7
	26	0.79	19.92	18.34	148.1	145	1920	160.2	2810	156.1
	27	0.85	19.92	18.22	158.9	145	2050	171.0	3005	166.9
	28	0.92	19.92	18.08	171.3	145	2200	183.4	3230	179.4
20	21	0.57	21.60	20.46	117.5	133	1545	128.6	2250	124.9
	22	0.62	21.60	20.36	127.5	133	1665	138.6	2430	134.9
	23	0.67	21.60	20.26	137.5	133	1785	148.6	2610	144.9
	24	0.72	21.60	20.16	147.4	133	1900	158.5	2785	154.8
	25	0.78	21.60	20.04	159.2	133	2045	170.3	3000	166.8
	26	0.84	21.60	19.92	170.9	133	2185	182.0	3210	178.4
	21	0.57	22.06	20.92	120.1	136	1575	131.4	2300	127.7
	22	0.62	22.06	20.82	130.3	136	1700	141.6	2480	137.9
	23	0.67	22.06	20.72	140.5	136	1820	151.8	2665	148.1
	24	0.72	22.06	20.62	150.6	136	1945	161.9	2845	158.1
	25	0.78	22.06	20.50	162.7	136	2090	174.0	3065	170.3
	26	0.84	22.06	20.38	174.7	171	2265	188.9	3315	184.1
	27	0.91	22.06	20.24	188.7	171	2435	203.0	3570	198.2
	28	0.98	22.06	20.10	202.5	171	2600	216.8	3815	212.0
24	21	0.63	25.80	24.54	155.4	179	2045	170.3	2975	165.3
	22	0.68	25.80	24.44	167.4	179	2190	182.3	3190	177.3
	23	0.73	25.80	24.34	179.4	179	2330	194.3	3410	189.4
	24	0.79	25.80	24.22	193.7	179	2505	208.6	3665	203.6
	25	0.85	25.80	24.10	207.9	179	2675	222.8	3920	217.8
	26	0.92	25.80	23.96	224.4	179	2870	239.3	4220	234.4
	21	0.63	26.32	25.06	158.6	182	2085	173.8	3035	168.7
	22	0.68	26.32	24.96	170.9	182	2235	186.1	3260	181.0
	23	0.73	26.32	24.86	183.1	182	2380	198.3	3480	193.2
	24	0.79	26.32	24.74	197.7	182	2555	212.9	3740	207.8
	25	0.85	26.32	24.62	212.2	182	2730	227.4	4000	222.3
	26	0.92	26.32	24.48	229.0	229	2975	248.1	4350	241.7
	27	0.99	26.32	24.34	245.8	229	3180	264.9	4655	258.5
	28	1.07	26.32	24.18	264.8	229	3405	283.9	4995	277.5

* Including bell. Calculated weight of pipe rounded off to nearest 5 lb.
† Average weight per foot based on calculated weight of pipe before rounding.

TABLE 6.3—STANDARD THICKNESSES AND WEIGHTS OF PIPE CENTRIFUGALLY CAST IN METAL MOLDS

These thicknesses and weights are for pipe laid without blocks, on flat-bottom trench, with tamped backfill, under 5 ft of cover. For other conditions, see Tables 6.2 and 6.4 hereof and ASA A21.1 (AWWA C101), "Manual for the Computation of Strength and Thickness of Cast Iron Pipe."

Size	Thickness	Outside Diam.	Weight Based on			
			12-ft Laying Length		18-ft Laying Length	
			Avg. Per Foot*	Per Length†	Avg. Per Foot*	Per Length†
in.			*lb*			
Class 50—50-psi Pressure—115-ft Head						
3	0.32	3.96	12.5	150	12.0	215
4	0.35	4.80	16.6	200	16.1	290
6	0.38	6.90	26.4	315	25.6	460
8	0.41	9.05	38.1	455	36.9	665
10	0.44	11.10	50.5	605	49.0	880
12	0.48	13.20	65.3	785	63.4	1140
14	0.48	15.30	76.2	915	74.1	1335
16	0.54	17.40	97.2	1165	94.5	1700
18	0.54	19.50	109.9	1320	106.7	1920
20	0.57	21.60	128.6	1545	124.9	2250
24	0.63	25.80	170.3	2045	165.3	2975
Class 100—100-psi Pressure—231-ft Head						
3	0.32	3.96	12.5	150	12.0	215
4	0.35	4.80	16.6	200	16.1	290
6	0.38	6.90	26.4	315	25.6	460
8	0.41	9.05	38.1	455	36.9	665
10	0.44	11.10	50.5	605	49.0	880
12	0.48	13.20	65.3	785	63.4	1140
14	0.51	15.30	80.4	965	78.2	1410
16	0.54	17.40	97.2	1165	94.5	1700
18	0.58	19.50	117.1	1405	113.9	2050
20	0.62	21.60	138.6	1665	134.9	2430
24	0.68	25.80	182.3	2190	177.3	3190
Class 150—150-psi Pressure—346-ft Head						
3	0.32	3.96	12.5	150	12.0	215
4	0.35	4.80	16.6	200	16.1	290
6	0.38	6.90	26.4	315	25.6	460
8	0.41	9.05	38.1	455	36.9	665
10	0.44	11.10	50.5	605	49.0	880
12	0.48	13.20	65.3	785	63.4	1140
14	0.51	15.65	82.4	990	80.2	1445
16	0.54	17.80	99.6	1195	96.9	1745
18	0.58	19.92	119.6	1435	116.3	2095
20	0.62	22.06	141.6	1700	137.9	2480
24	0.73	26.32	198.3	2380	193.2	3480

* Average weight per foot based on calculated weight of pipe before rounding.
† Including bell. Calculated weight of pipe rounded off to nearest 5 lb.

TABLE 6.3 (contd.)—STANDARD THICKNESSES AND WEIGHTS OF PIPE CENTRIFUGALLY CAST IN METAL MOLDS

These thicknesses and weights are for pipe laid without blocks, on flat-bottom trench, with tamped backfill, under 5 ft of cover. For other conditions, see Tables 6.2 and 6.4 hereof and ASA A21.1 (AWWA C101), "Manual for the Computation of Strength and Thickness of Cast Iron Pipe."

Size	Thickness	Outside Diam.	Weight Based on			
			12-ft Laying Length		18-ft Laying Length	
			Avg. Per Foot*	Per Length†	Avg. Per Foot*	Per Length†
in.			*lb*			
Class 200—200-psi Pressure—462-ft Head						
3	0.32	3.96	12.5	150	12.0	215
4	0.35	4.80	16.6	200	16.1	290
6	0.38	6.90	26.4	315	25.6	460
8	0.41	9.05	38.1	455	36.9	665
10	0.44	11.10	50.5	605	49.0	880
12	0.48	13.20	65.3	785	63.4	1140
14	0.55	15.65	88.1	1055	85.8	1545
16	0.58	17.80	106.1	1275	103.3	1860
18	0.63	19.92	128.8	1545	125.5	2260
20	0.67	22.06	151.8	1820	148.1	2665
24	0.79	26.32	212.9	2555	207.8	3740
Class 250—250-psi Pressure—577-ft Head						
3	0.32	3.96	12.5	150	12.0	215
4	0.35	4.80	16.6	200	16.1	290
6	0.38	6.90	26.4	315	25.6	460
8	0.41	9.05	38.1	455	36.9	665
10	0.44	11.10	50.5	605	49.0	880
12	0.52	13.20	70.1	840	68.3	1230
14	0.59	15.65	93.8	1125	91.6	1650
16	0.63	17.80	114.2	1370	111.5	2005
18	0.68	19.92	137.9	1655	134.8	2425
20	0.72	22.06	161.9	1945	158.1	2845
24	0.79	26.32	212.9	2555	207.8	3740
Class 300—300-psi Pressure—693-ft Head						
3	0.32	3.96	12.5	150	12.0	215
4	0.35	4.80	16.6	200	16.1	290
6	0.38	6.90	26.4	315	25.6	460
8	0.41	9.05	38.1	455	36.9	665
10	0.48	11.10	54.5	655	53.0	955
12	0.52	13.20	70.1	840	68.3	1230
14	0.59	15.65	93.8	1125	91.6	1650
16	0.68	17.80	122.2	1465	119.5	2150
18	0.73	19.92	147.0	1765	143.7	2585
20	0.78	22.06	174.0	2090	170.3	3065
24	0.85	26.32	227.4	2730	222.3	4000

* Average weight per foot based on calculated weight of pipe before rounding.
† Including bell. Calculated weight of pipe rounded off to nearest 5 lb.

TABLE 6.3 (contd.)—STANDARD THICKNESSES AND WEIGHTS OF PIPE CENTRIFUGALLY CAST IN METAL MOLDS

These thicknesses and weights are for pipe laid without blocks, on flat-bottom trench, with tamped backfill, under 5 ft of cover. For other conditions, see Tables 6.2 and 6.4 hereof and ASA A21.1 (AWWA C101), "Manual for the Computation of Strength and Thickness of Cast Iron Pipe."

Size	Thickness	Outside Diam.	Weight Based on			
			12-ft Laying Length		18-ft Laying Length	
			Avg. Per Foot*	Per Length†	Avg. Per Foot*	Per Length†
in.			*lb*			
Class 350—350-psi Pressure—808-ft Head						
3	0.32	3.96	12.5	150	12.0	215
4	0.35	4.80	16.6	200	16.1	290
6	0.38	6.90	26.4	315	25.6	460
8	0.41	9.05	38.1	455	36.9	665
10	0.52	11.10	58.4	700	56.9	1025
12	0.56	13.20	74.9	900	73.1	1315
14	0.64	15.65	100.9	1210	98.7	1775
16	0.68	17.80	122.2	1465	119.5	2150
18	0.79	19.92	160.2	1920	156.1	2810
20	0.84	22.06	188.9	2265	184.1	3315
24	0.92	26.32	248.1	2975	241.7	4350

* Average weight per foot based on calculated weight of pipe before rounding.
† Including bell. Calculated weight of pipe rounded off to nearest 5 lb.

TABLE 6.4

STANDARD THICKNESSES* OF PIPE CENTRIFUGALLY CAST IN METAL MOLDS

Laying Condition A—Flat-Bottom Trench, Without Blocks, Untamped Backfill
Laying Condition B—Flat-Bottom Trench, Without Blocks, Tamped Backfill
Laying Condition C—Pipe Laid on Blocks, Untamped Backfill
Laying Condition D—Pipe Laid on Blocks, Tamped Backfill

Size *in.*	Working Pressure *psi*	3½ ft of Cover				5 ft of Cover				8 ft of Cover			
		Laying Condition				Laying Condition				Laying Condition			
		A	B	C	D	A	B	C	D	A	B	C	D
		Thickness—*in.*											
3	50	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.38	0.32
	100	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.38	0.32
	150	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.38	0.32
	200	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.38	0.32
	250	0.32	0.32	0.32	0.32	0.32	0.32	0.35	0.32	0.32	0.32	0.38	0.32
	300	0.32	0.32	0.32	0.32	0.32	0.32	0.35	0.32	0.32	0.32	0.38	0.32
	350	0.32	0.32	0.32	0.32	0.32	0.32	0.35	0.32	0.32	0.32	0.38	0.32
4	50	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.41	0.35
	100	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.41	0.35
	150	0.35	0.35	0.35	0.35	0.35	0.35	0.38	0.35	0.35	0.35	0.41	0.35
	200	0.35	0.35	0.35	0.35	0.35	0.35	0.38	0.35	0.35	0.35	0.44	0.35
	250	0.35	0.35	0.35	0.35	0.35	0.35	0.38	0.35	0.35	0.35	0.44	0.35
	300	0.35	0.35	0.35	0.35	0.35	0.35	0.38	0.35	0.35	0.35	0.44	0.35
	350	0.35	0.35	0.38	0.35	0.35	0.35	0.38	0.35	0.35	0.35	0.44	0.35
6	50	0.38	0.38	0.41	0.38	0.38	0.38	0.44	0.38	0.38	0.38	0.48	0.38
	100	0.38	0.38	0.41	0.38	0.38	0.38	0.44	0.38	0.38	0.38	0.48	0.38
	150	0.38	0.38	0.41	0.38	0.38	0.38	0.44	0.38	0.38	0.38	0.48	0.38
	200	0.38	0.38	0.41	0.38	0.38	0.38	0.44	0.38	0.38	0.38	0.52	0.38
	250	0.38	0.38	0.44	0.38	0.38	0.38	0.44	0.38	0.38	0.38	0.52	0.38
	300	0.38	0.38	0.44	0.38	0.38	0.38	0.44	0.38	0.38	0.38	0.52	0.38
	350	0.38	0.38	0.44	0.38	0.38	0.38	0.48	0.38	0.38	0.38	0.52	0.38
8	50	0.41	0.41	0.44	0.41	0.41	0.41	0.48	0.41	0.41	0.41	0.52	0.41
	100	0.41	0.41	0.48	0.41	0.41	0.41	0.48	0.41	0.41	0.41	0.56	0.41
	150	0.41	0.41	0.48	0.41	0.41	0.41	0.48	0.41	0.41	0.41	0.56	0.41
	200	0.41	0.41	0.48	0.41	0.41	0.41	0.52	0.41	0.41	0.41	0.56	0.44
	250	0.41	0.41	0.48	0.41	0.41	0.41	0.52	0.41	0.44	0.41	0.56	0.44
	300	0.41	0.41	0.48	0.41	0.41	0.41	0.52	0.41	0.44	0.44	0.60	0.44
	350	0.41	0.41	0.52	0.41	0.44	0.41	0.52	0.44	0.48	0.44	0.60	0.48
10	50	0.44	0.44	0.48	0.44	0.44	0.44	0.52	0.44	0.44	0.44	0.60	0.48
	100	0.44	0.44	0.52	0.44	0.44	0.44	0.52	0.44	0.48	0.44	0.60	0.48
	150	0.44	0.44	0.52	0.44	0.44	0.44	0.56	0.44	0.48	0.44	0.60	0.48
	200	0.44	0.44	0.52	0.44	0.44	0.44	0.56	0.44	0.48	0.48	0.60	0.52
	250	0.44	0.44	0.56	0.44	0.48	0.44	0.56	0.48	0.52	0.48	0.65	0.52
	300	0.48	0.44	0.56	0.48	0.48	0.48	0.56	0.48	0.52	0.52	0.65	0.56
	350	0.48	0.48	0.56	0.48	0.52	0.52	0.60	0.52	0.56	0.52	0.65	0.56
12	50	0.48	0.48	0.52	0.48	0.48	0.48	0.56	0.48	0.52	0.48	0.65	0.52
	100	0.48	0.48	0.56	0.48	0.48	0.48	0.56	0.48	0.52	0.48	0.65	0.52
	150	0.48	0.48	0.56	0.48	0.48	0.48	0.56	0.48	0.52	0.52	0.65	0.56
	200	0.48	0.48	0.56	0.48	0.48	0.48	0.60	0.52	0.56	0.52	0.65	0.56
	250	0.52	0.48	0.60	0.52	0.52	0.52	0.60	0.52	0.56	0.56	0.70	0.60
	300	0.52	0.52	0.60	0.52	0.56	0.52	0.60	0.56	0.60	0.56	0.70	0.60
	350	0.56	0.56	0.60	0.56	0.56	0.56	0.65	0.60	0.60	0.60	0.76	0.65

* Thicknesses include allowances for foundry practice, corrosion, and either water hammer or truck load.

TABLE 6.4 (contd.)

STANDARD THICKNESSES* OF PIPE CENTRIFUGALLY CAST IN METAL MOLDS

Laying Condition A—Flat-Bottom Trench, Without Blocks, Untamped Backfill
Laying Condition B—Flat-Bottom Trench, Without Blocks, Tamped Backfill
Laying Condition C—Pipe Laid on Blocks, Untamped Backfill
Laying Condition D—Pipe Laid on Blocks, Tamped Backfill

Size *in.*	Working Pressure *psi*	3½ ft of Cover				5 ft of Cover				8 ft of Cover			
		Laying Condition				Laying Condition				Laying Condition			
		A	B	C	D	A	B	C	D	A	B	C	D
		Thickness—*in.*											
14	50	0.51	0.48	0.59	0.51	0.51	0.48	0.59	0.55	0.59	0.55	0.69	0.59
	100	0.51	0.48	0.59	0.55	0.55	0.51	0.64	0.55	0.59	0.55	0.69	0.64
	150	0.55	0.51	0.59	0.55	0.55	0.51	0.64	0.59	0.64	0.59	0.75	0.64
	200	0.55	0.51	0.64	0.59	0.55	0.55	0.64	0.59	0.64	0.59	0.75	0.69
	250	0.59	0.55	0.64	0.59	0.59	0.59	0.69	0.59	0.64	0.64	0.75	0.69
	300	0.59	0.59	0.69	0.59	0.64	0.59	0.69	0.64	0.69	0.64	0.81	0.69
	350	0.64	0.64	0.69	0.64	0.64	0.64	0.75	0.69	0.75	0.69	0.81	0.75
16	50	0.54	0.50	0.63	0.58	0.58	0.54	0.63	0.58	0.63	0.58	0.73	0.63
	100	0.54	0.54	0.63	0.58	0.58	0.54	0.68	0.58	0.63	0.58	0.73	0.68
	150	0.58	0.54	0.63	0.58	0.58	0.54	0.68	0.63	0.68	0.63	0.79	0.68
	200	0.58	0.58	0.68	0.63	0.63	0.58	0.68	0.63	0.68	0.63	0.79	0.73
	250	0.63	0.58	0.68	0.63	0.63	0.63	0.73	0.68	0.73	0.68	0.79	0.73
	300	0.63	0.63	0.73	0.68	0.68	0.68	0.73	0.68	0.73	0.73	0.85	0.79
	350	0.68	0.68	0.73	0.68	0.73	0.68	0.79	0.73	0.79	0.73	0.85	0.79
18	50	0.58	0.54	0.63	0.58	0.58	0.54	0.68	0.63	0.68	0.63	0.79	0.68
	100	0.58	0.54	0.68	0.63	0.63	0.58	0.73	0.63	0.68	0.63	0.79	0.73
	150	0.63	0.58	0.68	0.63	0.63	0.58	0.73	0.68	0.73	0.68	0.79	0.73
	200	0.63	0.58	0.73	0.68	0.68	0.63	0.73	0.68	0.73	0.68	0.85	0.79
	250	0.68	0.63	0.73	0.68	0.68	0.68	0.79	0.73	0.79	0.73	0.85	0.79
	300	0.68	0.68	0.79	0.73	0.73	0.73	0.79	0.79	0.79	0.79	0.92	0.85
	350	0.79	0.73	0.79	0.79	0.79	0.79	0.85	0.79	0.85	0.85	0.92	0.85
20	50	0.62	0.57	0.72	0.62	0.67	0.57	0.72	0.67	0.72	0.67	0.78	0.72
	100	0.62	0.57	0.72	0.67	0.67	0.62	0.78	0.67	0.72	0.67	0.84	0.78
	150	0.67	0.62	0.72	0.67	0.67	0.62	0.78	0.72	0.78	0.72	0.84	0.78
	200	0.67	0.62	0.78	0.72	0.72	0.67	0.78	0.72	0.78	0.72	0.91	0.84
	250	0.72	0.67	0.78	0.72	0.78	0.72	0.84	0.78	0.84	0.78	0.91	0.84
	300	0.78	0.72	0.84	0.78	0.78	0.78	0.84	0.84	0.84	0.84	0.98	0.91
	350	0.84	0.78	0.84	0.84	0.84	0.84	0.91	0.84	0.91	0.84	0.98	0.91
24	50	0.68	0.63	0.79	0.68	0.73	0.63	0.79	0.73	0.79	0.73	0.85	0.79
	100	0.73	0.63	0.79	0.73	0.73	0.68	0.85	0.79	0.85	0.73	0.92	0.85
	150	0.73	0.68	0.79	0.79	0.79	0.73	0.85	0.79	0.85	0.79	0.92	0.85
	200	0.79	0.73	0.85	0.79	0.79	0.79	0.92	0.85	0.92	0.85	0.99	0.92
	250	0.79	0.79	0.85	0.85	0.85	0.79	0.92	0.85	0.92	0.85	0.99	0.99
	300	0.85	0.85	0.92	0.85	0.92	0.85	0.99	0.92	0.99	0.92	1.07	0.99
	350	0.92	0.92	0.99	0.92	0.99	0.92	0.99	0.99	1.07	0.99	1.07	1.07

* Thicknesses include allowances for foundry practice, corrosion, and either water hammer or truck load.

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(AWWA C108-53)

American Standard Specifications

for

CAST IRON PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS, FOR WATER OR OTHER LIQUIDS

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Table 8.1—Standard Dimensions of Bells, Sockets, Spigot Beads and Outside Diameters—and Weights of Bells and Spigot Beads—of Pipe Centrifugally Cast in Sand-lined Molds.

Table 8.2—Standard Thicknesses, Diameters and Weights of Pipe Centrifugally Cast in Sand-lined Molds.

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Table 8.4—Standard Thicknesses of Pipe Centrifugally Cast in Sand-lined Molds (for laying conditions A, B, C and D, pressures 50–350, and 3½, 5 and 8 ft of cover).

NOTE 1—Tables showing additional thicknesses required for greater depths of cover and other conditions of laying will be found in ASA A21.1.

NOTE 2—Users of these tables are cautioned to select fittings having proper socket dimensions and thicknesses suited to the pressures. Pipe specified in these tables have outside diameters which will chamber correctly with existing standards for pipe and fittings.

Users of this document should make reference to "American Recommended Practice Manual for the Computation of Strength and Thickness of Cast Iron Pipe" (ASA A21.1) for complete information concerning the conditions which various thicknesses of pipe are designed to meet. The foreword of the Manual also contains a statement regarding the history of the specifications and references to other related documents.

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American Standard Specifications for

Cast Iron Pipe Centrifugally Cast in Sand-lined Molds, for Water or Other Liquids

This specification covers cast iron pipe centrifugally cast in sand-lined molds.

Sec. 8–1—Definitions

Purchaser. Wherever the word "purchaser" is used herein, it shall be understood to mean the actual purchaser of the pipe or his authorized agents acting within the scope of the duties entrusted to them.

Heat. A heat is a period during which a cupola or furnace is operated continuously.

Run. A run is a period of one or more shifts during which a shop is operated continuously.

Mixture of Iron. Mixture of iron is a combination of pig iron, scrap, coke and other raw materials charged to a cupola or furnace to give a desired composition of iron; or a combination of molten iron from one or more sources, made in a forehearth or ladle to give a desired composition of iron.

Source of Iron. A source of iron is a cupola, furnace or forehearth from which iron is delivered to a transfer or pouring ladle.

Forehearth. A forehearth is a refractory-lined receptacle for the temporary storage of molten iron from one or more cupolas or furnaces.

Sec. 8–2—Description of Pipe

The pipe shall be made with bell and spigot ends with beads cast on, or with plain ends or such other type of ends as may be agreed upon at the time of purchase. Pipe with bell-and-spigot ends shall conform to the dimensions and weights shown in the tables given in this document. Pipe with other types of ends shall comply with the dimensions agreed upon, but in all other respects shall fulfill the specifications hereinafter given. Pipe shall be straight and shall be true circles in sections, with the inner and outer surfaces concentric. Pipe shall be cast at least 12 ft in nominal laying length. This type of pipe is commonly made at present (1952) in 16-, 16½- and 20-ft lengths.

Sec. 8–3—Casting of Pipe

The pipe shall be centrifugally cast in sand-lined molds and shall remain in the sand for a sufficient length of time to prevent unequal contraction during cooling.

Sec. 8–4—Quality of Iron

8–4.1. All pipe shall be made of cast iron of good quality, and of such

character and so adapted in chemical composition to the thickness of the pipe to be cast, that the iron in the pipe shall be strong, tough, resilient, of even grain and soft enough for satisfactory drilling and cutting, and it shall comply with the physical specifications given in Sec. 8–17 and 8–18. The metal shall be remelted in a cupola or other suitable furnace.

8–4.2. The iron in the pipe shall not contain more than 0.90 per cent of phosphorus nor more than 0.12 per cent of sulphur. Samples for chemical analyses shall be taken by drilling completely through from skin to skin either acceptance test specimens or specimens cast for this purpose, but not to exceed three specimens per heat of approximately eight hours. In case of dispute, analyses will be determined on samples taken from the pipe in question.

Sec. 8–5—Quality of Castings

Pipe shall be smooth, free from scales, lumps, blisters, sand holes, laps and defects of every nature which unfit them for the use for which they are intended. No plugging, filling, burning-in or welding will be allowed except as permitted by the purchaser.

Sec. 8–6—Foundry Records

A record of the results of the following tests shall be made and retained for at least one year. Upon request such record will be available to the purchaser at the foundry. If written transcripts of the results of any of these tests are desired this fact shall be noted in the order for pipe, naming the tests of which transcripts are desired. The methods of testing and the dimensions of all test specimens are given in the Appendix.

8–6.1. *Chemical analyses.* Chemical analyses of each iron mixture used directly in the pouring of pipe, obtained as in Sec. 8–4.2, shall be made for silicon, sulphur, manganese, phosphorus and total carbon during the first hour and at intervals not to exceed three hours throughout the heat. If pipe are poured directly from the cupola, chemical analyses shall be made of iron from the first and from the last ladle. If the mixture is changed one or more times during a heat in order to produce a different iron, the time of taking samples shall be varied in such a way as to obtain representative tests of the iron at least at the beginning and end of each period during which the iron is intended to be constant in quality.

8–6.2. *Pouring temperatures.* The pouring temperature of the iron shall be taken at the casting ladle for each size of pipe at least once each hour.

8–6.3. *Talbot strip tests.* See Sec. 8–17.1.

8–6.4. *Test bar tests.* See Sec. 8–17.2.

8–6.5. *Periodic ring, strip and full-length bursting tests.* See Sec. 8–17 and 8–18.

Sec. 8–7—Marking Pipe

Each pipe shall have the weight and class designation conspicuously painted on it. In addition, each pipe shall have cast on it the manufacturer's mark, the year in which the pipe was cast and, when specified by the purchaser, initials not exceeding four in number. The letters and figures shall be on the outside surface of the pipe, and cast marks shall have dimensions not less than those indicated in the following table:

Nom. Pipe Diam. *in.*	Height of Letter *in.*	Relief of Letter *in.*
3–4	$\frac{1}{2}$	$\frac{1}{16}$
6–12	$\frac{3}{4}$	$\frac{3}{32}$
14–20	$1\frac{1}{4}$	$\frac{1}{8}$
24–48	2	$\frac{1}{4}$

Sec. 8–8—Inspection by Purchaser

8–8.1. *Power of purchaser to inspect.* The purchaser shall have free access at all times to all parts of any manufacturing plant which concern the manufacture of articles to be made for him. He may inspect the material, pattern work, molding, casting, coating and lining of the pipe. The forms, sizes, uniformity and conditions of all pipe herein referred to shall be subject to his inspection and approval, and he may reject, without subjection to hydrostatic test, any pipe which is not in conformity with the specifications or drawings. Any pipe rejected shall be so marked and any marks pertaining to the purchaser shall be chipped or erased from such pipe.

8–8.2. *Manufacturer to furnish men and materials.* The manufacturer shall provide tools, testing equipment, materials, labor and facilities necessary for the required testing, inspection and weighing of the pipe at the foundry.

8–8.3. *Report of purchaser's inspection.* The purchaser shall make written report daily to the foundry office of all pipe rejected with the causes for rejection.

Sec. 8–9—Inspection and Certification by Manufacturer

Should the purchaser have no inspector at the works, the manufacturer shall, if required by the purchaser, furnish a sworn statement that the inspection and all the tests have been made and met as specified. If written transcripts of any of these test results are required, including chemical tests if desired, a request specifying the tests of which transcripts are desired shall accompany the order.

Sec. 8–10—Pipe to Be Delivered Sound

All the pipe shall be delivered in all respects sound and in conformity with these specifications. The inspection shall not relieve the manufacturer of any of his obligations in this respect, and any defective pipe which may have passed the purchaser at the works or elsewhere shall be at all times liable to rejection when discovered, until the final completion and adjustment of the contract; provided, however, that the manufacturer shall not be held liable for pipe found to be damaged after they have been accepted at the agreed point of delivery, unless there shall be unmistakable evidence that the casting was originally defective or damaged before acceptance. Care shall be taken in handling the pipe not to injure the coating or lining, and no pipe or other material of any kind shall be placed in the pipe during transportation or at any other time after they have received the coating or lining.

Sec. 8–11—Cut Pipe

Defective spigot ends on pipe may be cut off in a manner which will produce a square end. Not more than 10 per cent of the total number of pipe of each size of a given order may be shipped as cut pipe. Such cut pipe when cut from 12-ft lengths shall have a nominal laying length of not less than 11 ft; pipe originally of 16-ft or greater length shall not be cut more than 2 ft.

Sec. 8–12—Tolerances or Maximum Permitted Variations

8–12.1. *Pipe and socket diameters.* Outside diameters of pipe barrels and spigot ends, and inside diameters of sockets, shall be kept as nearly as practicable to the specified dimensions. The inside diameters of the sockets and the outside diameters of the spigot ends shall be tested with circular gages. Tolerances or maximum permitted variations from standard dimensions are listed below:

Nom. Pipe Diam. *in.*	Tolerances *in.*
3–12	±0.06
14–24	±0.08
30–36	±0.10
42–48	±0.12

8–12.2. *Thickness.* The minus tolerances from standard thickness of pipe and dimensions *a*, *b*, *c* and *d* of the bells are as follows:

Nom. Pipe Diam. *in.*	Minus Tolerance *in.*
3–8	0.05
10–12	0.06
14–24	0.08
30–48	0.10

Note: In pipe barrel thickness, tolerances 0.02 in. greater than those listed above shall be permissible over areas not exceeding 8 in. in length in any direction.

8–12.3. *Weight.* The weight of no single pipe shall be less than the nominal tabulated weight by more than 5 per cent for pipe 12 in. or smaller in diameter, nor by more than 4 per cent for pipe larger than 12 in. in diameter The total weight of any order of 25 tons or more shall not be more than 2 per cent under the total nominal weight. The total excess weight to be paid for on orders of 25 tons or more shall not exceed 2 per cent of the nominal weight, and on orders of less than 25 tons shall not exceed 5 per cent of the nominal weight. An order is hereby defined as including all the pipe ordered under the terms of a specific contract or purchase order or a single order placed under the terms of a standing contract. Unless otherwise specified in the contract, a ton shall be 2,000 lb avoirdupois.

Sec. 8–13—Cleaning and Inspecting

All pipe shall have fins and other roughnesses chipped or ground off and shall be thoroughly cleaned, checked as to dimensions and also subjected to a careful inspection and a rolling test, before being coated or lined.

Sec. 8–14—Hydrostatic Test

Each pipe shall be subjected to a hydrostatic proof test. This test may be made either before or after a hot or cold bituminous dip or paint has been applied but shall be made before the cement mortar lining or any other special lining has been applied to pipe for which such lining is specified.

The pipe shall be under the test pressure for at least one-half minute. Any pipe showing defects by leaking, sweating or otherwise shall be rejected. The test pressures shall be in accordance with the table appearing on page 5.

Sec. 8–15—Weighing

Each length of pipe shall be weighed and the weight plainly marked on the outside or inside of the bell or spigot end. Pipe shall be weighed before the application of any lining or coating other than hot or cold bituminous dip or paint.

Table of Hydrostatic Test Pressures

Nom. Pipe Diam. *in.*	Nom. Barrel Thickness *in.*	Test Pressure *psi*
3–12	all thicknesses	500
14	0.57 and less	400
14	0.58 and over	500
16	0.60 and less	400
16	0.61 and over	500
18	0.65 and less	400
18	0.66 and over	500
20	0.70 and less	400
20	0.71 and over	500
24	0.75 and less	400
24	0.76 and over	500
30	0.88 and less	400
30	0.89 and over	500
36	0.98 and less	400
36	0.99 and over	500
42	1.09 and less	400
42	1.10 and over	500
48	1.18 and less	400
48	1.19 and over	500

Sec. 8–16—Linings and Exterior Coatings

Any particular lining or coating which is to be applied to the pipe shall be specified in the agreement made at the time of purchase. Separate specifications for cement-mortar lining (ASA A21.4, also known as AWWA C104), have been provided in connection with specifications for pipe.

No pipe for water works service shall be furnished without protective coating unless specifically ordered by the purchaser.

Sec. 8–17—Acceptance Tests for Physical Properties

The standard acceptance tests for the physical characteristics of the pipe shall be as follows:

Sec. 8–17.1—Talbot Strip Tests

Talbot strip tests shall be used to determine the acceptability of 3-in. to 24-in. pipe for modulus of rupture and secant modulus of elasticity.

17.1.1. *Sampling.* For sampling, every run shall be divided into periods of approximately three hours each, and at least one sample shall be taken during each three-hour period. The sample for the first period of the run shall be taken during the first hour or, if casting is direct from the cupola, from the first ladle. Samples shall be taken so that each size of pipe cast for two hours or longer during the run and each mixture or source of iron used for two hours or longer during the run shall be fairly represented.

17.1.2. *Method of testing.* The method of testing Talbot strips is given in Sec. 8–A1 of the Appendix.

17.1.3. *Acceptance values.* The acceptance values for tests on Talbot strips from 3-in. to 24-in. pipe shall be as follows:

Modulus of rupture: 40,000 psi minimum.

Secant modulus of elasticity: 10,000,000 psi maximum.

If the modulus of elasticity exceeds 10,000,000, the modulus of rupture shall exceed 40,000 in at least the same proportion.

Sec. 8–17.2—Two-Inch Test Bar Tests

ASTM standard (A48 Bar C) 2-in. diameter by 27-in. test bar tests shall be used to determine the acceptability of 30-in. to 48-in. pipe.

From each mixture of iron used to cast pipe of 30-in. to 48-in. sizes, 2-in. diameter test bars shall be cast and tested from the first ladle of iron, and at intervals not to exceed three hours during the heat.

For the record, from every 200 lengths, but from at least one pipe of each size each week, one Talbot strip shall be cut and tested, and shall meet the requirements of Sec. 8–17.1.3.

At the manufacturer's option, Talbot strips may be tested instead of test bars. If Talbot strips are tested, they shall meet the requirements of Sec. 8–17.1.3.

Test bars shall have a minimum breaking load of 6,000 lb and a deflection of 0.15 in. plus 0.01 in. for each 500 lb that the breaking load exceeds 6,000 lb.

These test bar values apply only to thickness classes 21 to 25 in pipe designed with an 18,000-psi tensile strength in bursting and a 40,000-psi modulus of rupture of the ring.

Sec. 8–18—Periodic Ring Tests and Full-Length Bursting Tests

The manufacturer shall periodically make such bursting tests and ring tests in conjunction with strip tests that he can certify the design values of the modulus of rupture (40,000 psi) and the tensile strength of the iron in the pipe (18,000 psi). These tests shall be made in accordance with dimensions and methods given in the Appendix.

Pipe for these periodic ring and bursting tests shall be so selected that they will be representative of the sizes and various thicknesses of each size cast. Ring tests shall not be made on 3-in. and 4-in. pipe.

Tests of Talbot strips cut from the ring, as provided in the Appendix, shall be made in conjunction with ring and bursting tests. At least three Talbot strips shall be tested from each burst pipe and one of these strips shall come from the ring. For pipe for which rings less than 10½ in. long are used, the Talbot strip shall come from parts other than the ring.

Tests and records shall include the modulus of rupture of each strip and ring and also the modulus of elasticity of each strip and of each ring 12 in. and larger; the breaking load and deflection of each test bar shall also be included.

At the purchaser's request, the manufacturer shall furnish a written transcript of ring and bursting tests and tests on Talbot strips made in connection therewith for a period not exceeding one year and for such sizes as requested.

Unless there is a record of satisfactory tests equivalent to those hereinafter described, extending to within three months or less of the time to begin manufacture of an order for pipe of any size from 30 in. to 48 in., the producer shall test three pipe from the first day's production and one each succeeding day for the next four days. If all the tests meet the specifications, he shall test one pipe every five days for the next three weeks, and if all those meet the specifications, he shall test one pipe each month. In the case of a failure of any test, the same series of tests as above specified shall be repeated. If there is a lapse of more than one month in the manufacture of such pipe, the monthly test shall be made on a pipe from the first day's run. If the tests are all satisfactory, the number of pipe tested shall not exceed 3 per cent of the order.

Sec. 8–19—Additional Tests Required by Purchaser

If more or other tests than those provided in these specifications are required by the purchaser, such tests

shall be specified in the invitation for bids.

Sec. 8–20—Defective Specimens and Retests

8–20.1. If any test specimen shows defective machining or lack of continuity of metal, it may be discarded and replaced by another specimen. If any sound test specimen fails to meet the specified requirements, the purchaser may permit a retest on two additional sound specimens from pipe cast in the same period as the specimen which failed; both of the additional specimens shall meet the prescribed tests to be acceptable.

8–20.2. Test bars may be cast in pairs and at least one bar from each pair shall be tested, but the manufacturer shall have the right to test both bars, in which case the better bar shall be taken as representative.

8–20.3. If a routine test bar test fails to meet the requirements, the manufacturer shall have the right to substitute two Talbot strips cut from a pipe cast with iron represented by the failed test bar test. If both strip tests meet the requirements, the pipe for that period shall be acceptable.

Sec. 8–21—Rejection of Pipe

If any routine chemical analysis fails to meet the chemical requirements of Sec. 8–4.2, or if any acceptance test fails to meet the requirements of Sec. 8–17.1.3, 8–17.2 and 8–20, the pipe cast in the period shall be rejected except as subject to the provisions of Sec. 8–22.

Sec. 8–22—Limiting Rejection

The manufacturer may limit the amount of rejection by making similar additional tests of pipe of the same size as that rejected until the rejected lot is bracketed in order of manufacture by two acceptable tests. If a period is rejected, the acceptability of pipe of different sizes from that rejected may be established by making the routine acceptance tests for these sizes.

Appendix *

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Sec. 8-A3—Full-Length Bursting Tests

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Tables †

Table 8.1—Standard Dimensions of Bells, Sockets, Spigot Beads and Outside Diameters—and Weights of Bells and Spigot Beads—of Pipe Centrifugally Cast in Sand-lined Molds.

Table 8.2—Standard Thicknesses, Diameters and Weights of Pipe Centrifugally Cast in Sand-lined Molds.

Table 8.3—Standard Thicknesses and Weights of Pipe Centrifugally Cast in Sand-lined Molds.

Table 8.4—Standard Thicknesses of Pipe Centrifugally Cast in Sand-lined Molds.

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* This Appendix is a part of ASA A21.8—American Standard Specifications for Cast Iron Pipe Centrifugally Cast in Sand-lined Molds, for Water or Other Liquids.

† Data on thicknesses required for greater depths of cover and conditions of laying other than those assumed in the following tables will be found in Appendix B of ASA A21.1—American Recommended Practice Manual for the Computation of Strength and Thickness of Cast Iron Pipe.

Users of the following tables are cautioned to select fittings having proper socket dimensions and thicknesses suited to the pressures. Pipe specified in these tables have outside diameters which will chamber correctly with existing standards for pipe and fittings.

Sec. 8–A1—Talbot Strip Tests

Talbot strips (Fig. 8.1) shall be machined longitudinally from each pipe specimen selected for testing by this method. These Talbot strips may be cut from a part of the ring little stressed in the ring test—i.e., near one of the elements marked *a* in the illustration of the ring test (Fig. 8.2). The strips in any case will be in cross section as indicated in Fig. 8.1—i.e., will have for their width the thickness of the pipe and for their depth, 0.50 in. Their length shall be at least $10\frac{1}{2}$ in. These strips shall be tested as beams on supports 10 in. apart with loads applied perpendicularly to the machined faces at two points $3\frac{1}{2}$ in. from the supports. The breaking load and

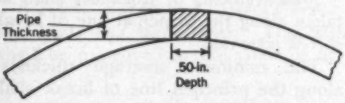


FIG. 8.1. Position From Which Talbot Strip Is Cut

the deflection shall be observed and recorded.

The strip shall be accurately calipered at the point of rupture and the modulus of rupture, R, shall be calculated by the usual beam formula, which for this case reduces to the expression:

$$R = \frac{10\,W}{td^2}$$

The secant modulus of elasticity, E_s, in pounds per square inch, shall be computed by the formula:

$$E_s = \frac{21.3R}{dy}$$

In the above formulas, R is the modulus of rupture (psi), E_s is the secant modulus of elasticity (psi), W is the breaking load (lb), d is the depth (in.) of the strip (intended to be 0.50 in.), t is the width (in.) of the strip (pipe thickness) and y is the deflection (in.) of the strip at the center at breaking load.

Sec. 8–A2—Ring Tests

The maximum length of any ring shall not exceed 12 in.; for pipe 14 in. and larger, the minimum length shall be $10\frac{1}{2}$ in.; for pipe 12 in. and smaller, the minimum length shall be one-half the nominal diameter of the pipe. Each ring shall be tested by the three-edge bearing method as indicated in Fig. 8.2.

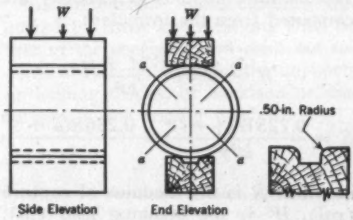


FIG. 8.2. Assembly for Ring Test

The lower bearing for the ring shall consist of two strips with vertical sides having their interior top edges rounded to a radius of approximately $\frac{1}{2}$ in. The strips shall be of hard wood or of metal. If of metal, a piece of fabric or leather approximately $\frac{3}{16}$ in. thick shall be laid over them. They shall be straight and shall be securely fastened to a rigid block, with their interior vertical faces the following distances apart:

Nom. Pipe Diam. *in.*	Bearing Strip Spacing *in.*
3–12	$\frac{1}{2}$
14–24	1
30–48	2

The upper bearing shall be an oak block, straight and true from end to end. The upper and lower bearings shall extend the full length of the ring. The ring shall be placed symmetrically between the two bearings, and the center of application of the load shall be so placed that the vertical deformation at the two ends of the ring shall be approximately equal. If the ring is not uniform in thickness, it shall be so placed that the thick and thin portions are near the ends of the horizontal diameter.

A record of the breaking load and the vertical deformation of each ring tested shall be made. The modulus of rupture and modulus of elasticity are computed from the formulas:

$$R = 0.954 \frac{W(d + t)}{bt^2}$$

$$E = \frac{0.225W(d + t)^3}{bt^3y} = \frac{0.236R(d + t)^3}{ty}$$

in which R is the modulus of rupture (psi), W is the breaking load (lb), d is the average inside diameter (in.) of the ring, t is the average thickness (in.) of metal along the line of fracture, b is the length (in.) of the ring, E is the modulus of elasticity (psi) and y is the vertical deformation (in.) of the ring at the center.

Sec. 8–A3—Full-Length Bursting Tests

The bursting tensile strength shall be determined by testing full-length pipe (less the amount cut off for ring and strip test specimens) to destruction by hydraulic pressure. Bells may be removed to facilitate testing. A suitable means for holding the end thrust shall be used which will not subject the pipe to endwise tension or compression, or other parasitic stresses. A calibrated pressure gage shall be used for determining the bursting pressure. This gage shall be connected to the interior of the test pipe by a separate connection from that which supplies water for the test. The unit tensile strength in bursting shall be obtained by the use of the formula:

$$S = \frac{Pd}{2t}$$

in which S is the bursting tensile strength (psi) of the iron, P is the internal pressure (psi) at bursting, d is the average inside diameter (in.) of the pipe and t is the minimum average thickness (in.) of the pipe along the principal line of break.

Measurements of thickness shall be taken along the principal line of break at 1-ft intervals.

The minimum average thickness along the principal line of break shall be obtained by averaging the measurements at the thinnest section at a weight of two and at the adjacent sections on each side at a weight of one each; or, if the thinnest section is at the end of the break, by averaging this thinnest-section measurement at a weight of two and the measurements of the adjacent section and the next section at a weight of one each.

Sec. 8–A4—Test Bars

8–A4.1. *Dimensions.* Test bars for pipe of 30-in. to 48-in. diameter shall be 2 in. in diameter and not less than 26 in. long. Individual test bars may vary as much as 3 per cent from the standard diameter.

8–A4.2. *Method of casting.* The bars shall be cast vertically in well faced, dry sand molds provided with

a suitable pouring basin and mounted on a suitable refractory foundation. Metal for the bars shall be obtained by using a small heated ladle taking its metal from the main ladle from which the pipe is to be poured. The metal shall be taken after all alloys and other additional metal, except cast-iron pipe scrap for cooling, have been added to the main ladle and become melted. The bars shall not be removed from the mold before they have cooled to 500°F.

8–A4.3. *Method of testing.* The bars shall be broken as beams by placing them on supports 24 in. apart and applying the load at the center of the span. The breaking load and the corresponding deflection shall be observed and recorded.

8–A4.4. *Correcting observed breaking loads and deflections.* The bars shall be measured at the point of application of the load and the results corrected to standard dimensions by the conventional beam formula (for bars of 2-in. diameter):

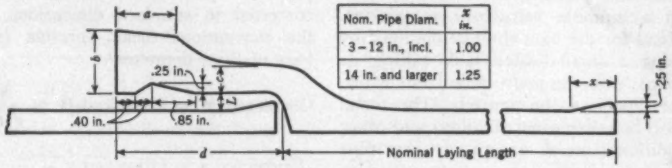
$$\text{Corrected } W = \text{Observed } W \times \frac{8}{d_h d_v^2}$$

$$\text{Corrected } y = \text{Observed } y \times \frac{d_v}{2}$$

in which W is the breaking load (lb), d_h is the measured horizontal diameter (in.), d_v is the measured vertical diameter (in.) and y is the deflection (in.) at breaking.

Sec. 8–A5—Deflection Measurements

All deflection measurements required by these specifications shall be that of the specimen and shall not include any compression of the supports or loading blocks, or backlash or distortion of the testing machine.



Nom. Pipe Diam.	x in.
3–12 in., incl.	1.00
14 in. and larger	1.25

TABLE 8.1

STANDARD DIMENSIONS OF BELLS, SOCKETS, SPIGOT BEADS AND OUTSIDE DIAMETERS—AND WEIGHTS OF BELLS AND SPIGOT BEADS—OF PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS

Nom. Diam.	Pipe Thickness		Pipe Outside Diam.	Dimensions of Bells						Weight of Bell and Spigot Bead
	From	To		Socket Diam.	Thickness of Joint L	Socket Depth d	a	b	c	
	in.									lb
3	0.32	0.38	3.96	4.76	0.40	3.50	1.25	1.25	0.52	15
4	0.35	0.44	4.80	5.60	0.40	3.50	1.25	1.30	0.55	19
	0.35	0.44	5.00	5.80	0.40	3.50	1.25	1.30	0.55	20
6	0.38	0.41	6.90	7.70	0.40	3.50	1.38	1.35	0.48	26
	0.44	0.48	6.90	7.70	0.40	3.50	1.38	1.35	0.64	29
	0.38	0.41	7.10	7.90	0.40	3.50	1.38	1.35	0.48	27
	0.44	0.52	7.10	7.90	0.40	3.50	1.38	1.35	0.64	30
8	0.41	0.44	9.05	9.85	0.40	4.00	1.38	1.45	0.52	37
	0.48	0.56	9.05	9.85	0.40	4.00	1.38	1.45	0.68	43
	0.41	0.44	9.30	10.10	0.40	4.00	1.38	1.45	0.52	38
	0.48	0.60	9.30	10.10	0.40	4.00	1.38	1.45	0.68	44
10	0.44	0.48	11.10	11.90	0.40	4.00	1.50	1.55	0.56	50
	0.52	0.60	11.10	11.90	0.40	4.00	1.50	1.55	0.73	56
	0.44	0.48	11.40	12.20	0.40	4.00	1.50	1.55	0.56	51
	0.52	0.65	11.40	12.20	0.40	4.00	1.50	1.55	0.73	58
12	0.48	0.52	13.20	14.00	0.40	4.00	1.50	1.60	0.60	63
	0.56	0.65	13.20	14.00	0.40	4.00	1.50	1.60	0.79	71
	0.48	0.52	13.50	14.30	0.40	4.00	1.50	1.60	0.60	64
	0.56	0.70	13.50	14.30	0.40	4.00	1.50	1.60	0.79	73
	0.76		13.50	14.30	0.40	4.00	1.50	1.60	0.95	81
14	0.48	0.55	15.30	16.10	0.40	4.00	1.50	1.70	0.64	79
	0.59	0.69	15.30	16.10	0.40	4.00	1.50	1.70	0.85	88
	0.48	0.55	15.65	16.45	0.40	4.00	1.50	1.70	0.64	80
	0.59	0.75	15.65	16.45	0.40	4.00	1.50	1.70	0.85	90
	0.81		15.65	16.45	0.40	4.00	1.50	1.70	1.01	99

TABLE 8.1 (contd.)

STANDARD DIMENSIONS OF BELLS, SOCKETS, SPIGOT BEADS AND OUTSIDE DIAMETERS—AND WEIGHTS OF BELLS AND SPIGOT BEADS—OF PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS

Nom. Diam.	Pipe Thickness		Pipe Outside Diam.	Dimensions of Bells						Weight of Bell and Spigot Bead
	From	To		Socket Diam.	Thickness of Joint L	Socket Depth d	a	b	c	
	in.									lb
16	0.50	0.58	17.40	18.40	0.50	4.00	1.75	1.75	0.67	96
	0.63	0.73	17.40	18.40	0.50	4.00	1.75	1.75	0.89	108
	0.50	0.58	17.80	18.80	0.50	4.00	1.75	1.75	0.67	98
	0.63	0.79	17.80	18.80	0.50	4.00	1.75	1.75	0.89	110
	0.85		17.80	18.80	0.50	4.00	1.75	1.75	1.06	122
18	0.54	0.63	19.50	20.50	0.50	4.00	1.75	1.80	0.72	115
	0.68	0.79	19.50	20.50	0.50	4.00	1.75	1.80	0.95	128
	0.54	0.63	19.92	20.92	0.50	4.00	1.75	1.80	0.72	117
	0.68	0.85	19.92	20.92	0.50	4.00	1.75	1.80	0.95	130
	0.92		19.92	20.92	0.50	4.00	1.75	1.80	1.14	145
20	0.57	0.67	21.60	22.60	0.50	4.00	1.75	1.90	0.76	135
	0.72	0.84	21.60	22.60	0.50	4.00	1.75	1.90	1.01	149
	0.57	0.67	22.06	23.06	0.50	4.00	1.75	1.90	0.76	137
	0.72	0.91	22.06	23.06	0.50	4.00	1.75	1.90	1.01	152
	0.98		22.06	23.06	0.50	4.00	1.75	1.90	1.21	171
24	0.63	0.73	25.80	26.80	0.50	4.00	2.00	2.05	0.85	171
	0.79	0.92	25.80	26.80	0.50	4.00	2.00	2.05	1.04	191
	0.63	0.73	26.32	27.32	0.50	4.00	2.00	2.05	0.85	174
	0.79	0.92	26.32	27.32	0.50	4.00	2.00	2.05	1.04	194
	0.99	1.07	26.32	27.32	0.50	4.00	2.00	2.05	1.29	221
30	0.73	0.85	32.00	33.00	0.50	4.50	2.00	2.25	0.97	254
	0.92	1.07	32.00	33.00	0.50	4.50	2.00	2.25	1.20	280
	1.16		32.00	33.00	0.50	4.50	2.00	2.25	1.49	318
36	0.81	0.94	38.30	39.30	0.50	4.50	2.00	2.45	1.09	347
	1.02	1.19	38.30	39.30	0.50	4.50	2.00	2.45	1.35	390
	1.29	1.39	38.30	39.30	0.50	4.50	2.00	2.45	1.67	445
42	0.90	1.05	44.50	45.50	0.50	5.00	2.00	2.65	1.20	450
	1.13	1.32	44.50	45.50	0.50	5.00	2.00	2.65	1.48	510
	1.43	1.54	44.50	45.50	0.50	5.00	2.00	2.65	1.83	585
48	0.98	1.14	50.80	51.80	0.50	5.00	2.00	2.85	1.29	556
	1.23	1.44	50.80	51.80	0.50	5.00	2.00	2.85	1.61	634
	1.56	1.68	50.80	51.80	0.50	5.00	2.00	2.85	1.99	735

TABLE 8.2

STANDARD THICKNESSES, DIAMETERS AND WEIGHTS OF PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS

Nom. Diam. *in.*	Thickness Class	Thickness *in.*	Outside Diam. *in.*	Inside Diam. *in.*	Weight of Barrel per Foot *lb*	Weight of Bell and Spigot Bead *lb*	Weight (*lb*) Based on 16-ft Laying Length		Weight (*lb*) Based on 16⅔-ft Laying Length		Weight (*lb*) Based on 20-ft Laying Length	
							Per Length*	Avg. per Foot†	Per Length*	Avg. per Foot†	Per Length*	Avg. per Foot†
3	22	0.32	3.96	3.32	11.4	15	195	12.4	205	12.3		
	23	0.35	3.96	3.26	12.4	15	215	13.4	220	13.3		
	24	0.38	3.96	3.20	13.3	15	230	14.3	235	14.2		
4	22	0.35	4.80	4.10	15.3	19	265	16.5	270	16.4		
	23	0.38	4.80	4.04	16.5	19	285	17.7	290	17.6		
	24	0.41	4.80	3.98	17.6	19	300	18.8	310	18.7		
	25	0.44	4.80	3.92	18.8	19	320	20.0	330	19.9		
	22	0.35	5.00	4.30	16.0	20	275	17.2	285	17.1		
	23	0.38	5.00	4.24	17.2	20	295	18.5	305	18.4		
	24	0.41	5.00	4.18	18.4	20	315	19.7	325	19.6		
	25	0.44	5.00	4.12	19.7	20	335	21.0	345	20.9		
6	22	0.38	6.90	6.14	24.3	26	415	25.9	425	25.8		
	23	0.41	6.90	6.08	26.1	26	445	27.7	455	27.6		
	24	0.44	6.90	6.02	27.9	29	475	29.7	490	29.6		
	25	0.48	6.90	5.94	30.2	29	510	32.0	525	31.9		
	22	0.38	7.10	6.34	25.0	27	425	26.7	440	26.6		
	23	0.41	7.10	6.28	26.9	27	455	28.5	470	28.4		
	24	0.44	7.10	6.22	28.7	30	490	30.6	505	30.5		
	25	0.48	7.10	6.14	31.1	30	530	33.0	545	32.9		
	26	0.52	7.10	6.06	33.5	30	565	35.4	585	35.3		
8	22	0.41	9.05	8.23	34.7	37	590	37.0	610	36.9		
	23	0.44	9.05	8.17	37.1	37	630	39.5	650	39.4		
	24	0.48	9.05	8.09	40.3	43	690	43.0	710	42.9		
	25	0.52	9.05	8.01	43.5	43	740	46.2	760	46.1		
	26	0.56	9.05	7.93	46.6	43	790	49.3	810	49.2		
	22	0.41	9.30	8.48	35.7	38	610	38.1	625	38.0		
	23	0.44	9.30	8.42	38.2	38	650	40.6	670	40.5		
	24	0.48	9.30	8.34	41.5	44	710	44.3	730	44.2		
	25	0.52	9.30	8.26	44.8	44	760	47.6	785	47.5		
	26	0.56	9.30	8.18	48.0	44	810	50.7	835	50.6		
	27	0.60	9.30	8.10	51.2	44	865	54.0	890	53.9		

* Including bell and spigot bead. Calculated weight of pipe rounded off to nearest 5 lb.
† Average weight per foot based on calculated weight of pipe before rounding.

TABLE 8.2 (contd.)

STANDARD THICKNESSES, DIAMETERS AND WEIGHTS OF PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS

Nom. Diam. *in.*	Thickness Class	Thickness *in.*	Outside Diam. *in.*	Inside Diam. *in.*	Weight of Barrel per Foot *lb*	Weight of Bell and Spigot Bead *lb*	Weight (*lb*) Based on					
							16-ft Laying Length		16½-ft Laying Length		20-ft Laying Length	
							Per Length*	Avg. per Foot†	Per Length*	Avg. per Foot†	Per Length*	Avg. per Foot†
10	22	0.44	11.10	10.22	46.0	50	785	49.1	810	49.0		
	23	0.48	11.10	10.14	50.0	50	850	53.1	875	53.0		
	24	0.52	11.10	10.06	53.9	56	920	57.4	945	57.3		
	25	0.56	11.10	9.98	57.9	56	980	61.4	1,010	61.3		
	26	0.60	11.10	9.90	61.8	56	1,045	65.3	1,075	65.2		
	22	0.44	11.40	10.52	47.3	51	810	50.5	830	50.4		
	23	0.48	11.40	10.44	51.4	51	875	54.6	900	54.5		
	24	0.52	11.40	10.36	55.5	58	945	59.1	975	59.0		
	25	0.56	11.40	10.28	59.5	58	1,010	63.1	1,040	63.0		
	26	0.60	11.40	10.20	63.5	58	1,075	67.1	1,105	67.0		
	27	0.65	11.40	10.10	68.5	58	1,155	72.1	1,190	72.0		
12	22	0.48	13.20	12.24	59.8	63	1,020	63.7	1,050	63.6	1,260	63.0
	23	0.52	13.20	12.16	64.6	63	1,095	68.5	1,130	68.4	1,355	67.8
	24	0.56	13.20	12.08	69.4	71	1,180	73.8	1,215	73.7	1,460	73.0
	25	0.60	13.20	12.00	74.1	71	1,255	78.5	1,295	78.4	1,555	77.7
	26	0.65	13.20	11.90	80.0	71	1,350	84.4	1,390	84.3	1,670	83.6
	22	0.48	13.50	12.54	61.3	64	1,045	65.3	1,075	65.2	1,290	64.5
	23	0.52	13.50	12.46	66.2	64	1,125	70.2	1,155	70.1	1,390	69.4
	24	0.56	13.50	12.38	71.0	73	1,210	75.6	1,245	75.4	1,495	74.7
	25	0.60	13.50	12.30	75.9	73	1,285	80.4	1,325	80.3	1,590	79.6
	26	0.65	13.50	12.20	81.9	73	1,385	86.5	1,425	86.3	1,710	85.6
	27	0.70	13.50	12.10	87.8	73	1,480	92.4	1,520	92.2	1,830	91.4
	28	0.76	13.50	11.98	94.9	81	1,600	100.0	1,645	99.7	1,980	99.0
14	21	0.48	15.30	14.34	69.7	79	1,195	74.6	1,230	74.5	1,475	73.7
	22	0.51	15.30	14.28	73.9	79	1,260	78.8	1,300	78.7	1,555	77.8
	23	0.55	15.30	14.20	79.5	79	1,350	84.4	1,390	84.3	1,670	83.4
	24	0.59	15.30	14.12	85.1	88	1,450	90.6	1,490	90.4	1,790	89.4
	25	0.64	15.30	14.02	92.0	88	1,560	97.5	1,605	97.3	1,930	96.4
	26	0.69	15.30	13.92	98.8	88	1,670	104.3	1,720	104.1	2,065	103.2
	21	0.48	15.65	14.69	71.4	80	1,220	76.4	1,260	76.3	1,510	75.4
	22	0.51	15.65	14.63	75.7	80	1,290	80.7	1,330	80.5	1,595	79.7
	23	0.55	15.65	14.55	81.4	80	1,380	86.4	1,425	86.3	1,710	85.4
	24	0.59	15.65	14.47	87.1	90	1,485	92.7	1,525	92.5	1,830	91.5
	25	0.64	15.65	14.37	94.2	90	1,595	99.8	1,645	99.7	1,975	98.7
	26	0.69	15.65	14.27	101.2	90	1,710	106.8	1,760	106.7	2,115	105.7
	27	0.75	15.65	14.15	109.5	90	1,840	115.1	1,895	114.9	2,280	114.0
	28	0.81	15.65	14.03	117.8	99	1,985	124.0	2,045	123.8	2,455	122.8

* Including bell and spigot bead. Calculated weight of pipe rounded off to nearest 5 lb.
† Average weight per foot based on calculated weight of pipe before rounding.

TABLE 8.2 (contd.)

STANDARD THICKNESSES, DIAMETERS AND WEIGHTS OF PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS

Nom. Diam. *in.*	Thickness Class	Thickness *in.*	Outside Diam. *in.*	Inside Diam. *in.*	Weight of Barrel per Foot *lb*	Weight of Bell and Spigot Bead *lb*	Weight (*lb*) Based on					
							16-ft Laying Length		16½-ft Laying Length		20-ft Laying Length	
							Per Length*	Avg. per Foot†	Per Length*	Avg. per Foot†	Per Length*	Avg. per Foot†
16	21	0.50	17.40	16.40	82.8	96	1,420	88.8	1,460	88.6	1,750	87.6
	22	0.54	17.40	16.32	89.2	96	1,525	95.2	1,570	95.0	1,880	94.0
	23	0.58	17.40	16.24	95.6	96	1,625	101.6	1,675	101.4	2,010	100.4
	24	0.63	17.40	16.14	103.6	108	1,765	110.4	1,815	110.1	2,180	108.9
	25	0.68	17.40	16.04	111.4	108	1,890	118.2	1,945	117.9	2,335	116.7
	26	0.73	17.40	15.94	119.3	108	2,015	126.0	2,075	125.8	2,495	124.7
	21	0.50	17.80	16.80	84.8	98	1,455	90.9	1,495	90.7	1,795	89.7
	22	0.54	17.80	16.72	91.4	98	1,560	97.5	1,605	97.3	1,925	96.3
	23	0.58	17.80	16.64	97.9	98	1,665	104.0	1,715	103.8	2,055	102.8
	24	0.63	17.80	16.54	106.0	110	1,805	112.9	1,860	112.7	2,230	111.4
	25	0.68	17.80	16.44	114.1	110	1,935	121.0	1,995	120.8	2,390	119.4
	26	0.73	17.80	16.34	122.1	110	2,065	129.0	2,125	128.8	2,550	127.6
	27	0.79	17.80	16.22	131.7	110	2,215	138.5	2,285	138.4	2,745	137.2
	28	0.85	17.80	16.10	141.2	122	2,380	148.8	2,450	148.6	2,945	147.3
18	21	0.54	19.50	18.42	100.4	115	1,720	107.6	1,770	107.4	2,125	106.2
	22	0.58	19.50	18.34	107.6	115	1,835	114.8	1,890	114.6	2,265	113.3
	23	0.63	19.50	18.24	116.5	115	1,980	123.7	2,035	123.4	2,445	122.2
	24	0.68	19.50	18.14	125.4	128	2,135	133.4	2,195	133.1	2,635	131.7
	25	0.73	19.50	18.04	134.3	128	2,275	142.3	2,345	142.1	2,815	140.7
	26	0.79	19.50	17.92	144.9	128	2,445	152.9	2,520	152.7	3,025	151.3
	21	0.54	19.92	18.84	102.6	117	1,760	109.9	1,810	109.7	2,170	108.4
	22	0.58	19.92	18.76	109.9	117	1,875	117.2	1,930	117.0	2,315	115.8
	23	0.63	19.92	18.66	119.1	117	2,025	126.5	2,080	126.2	2,500	125.0
	24	0.68	19.92	18.56	128.2	130	2,180	136.3	2,245	136.1	2,695	134.7
	25	0.73	19.92	18.46	137.3	130	2,325	145.4	2,395	145.2	2,875	143.7
	26	0.79	19.92	18.34	148.1	130	2,500	156.2	2,575	156.1	3,090	154.6
	27	0.85	19.92	18.22	158.9	130	2,670	167.0	2,750	166.8	3,310	165.4
	28	0.92	19.92	18.08	171.3	145	2,885	180.4	2,970	180.1	3,570	178.6
20	21	0.57	21.60	20.46	117.5	135	2,015	125.9	2,075	125.7	2,485	124.2
	22	0.62	21.60	20.36	127.5	135	2,175	135.9	2,240	135.7	2,685	134.2
	23	0.67	21.60	20.26	137.5	135	2,335	145.9	2,405	145.7	2,885	144.2
	24	0.72	21.60	20.16	147.4	149	2,505	156.7	2,580	156.4	3,095	154.7
	25	0.78	21.60	20.04	159.2	149	2,695	168.5	2,775	168.2	3,335	166.7
	26	0.84	21.60	19.92	170.9	149	2,885	180.2	2,970	179.9	3,565	178.3

* Including bell and spigot bead. Calculated weight of pipe rounded off to nearest 5 lb.
† Average weight per foot based on calculated weight of pipe before rounding

TABLE 8.2 (contd.)

STANDARD THICKNESSES, DIAMETERS AND WEIGHTS OF PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS

Nom. Diam. *in.*	Thickness Class	Thickness *in.*	Outside Diam. *in.*	Inside Diam. *in.*	Weight of Barrel per Foot *lb*	Weight of Bell and Spigot Bead *lb*	Weight (*lb*) Based on					
							16-ft Laying Length		16½-ft Laying Length		20-ft Laying Length	
							Per Length*	Avg. per Foot†	Per Length*	Avg. per Foot†	Per Length*	Avg. per Foot†
20	21	0.57	22.06	20.92	120.1	137	2,060	128.7	2,120	128.4	2,540	127.0
	22	0.62	22.06	20.82	130.3	137	2,220	138.9	2,285	138.6	2,745	137.2
	23	0.67	22.06	20.72	140.5	137	2,385	149.1	2,455	148.8	2,945	147.3
	24	0.72	22.06	20.62	150.6	152	2,560	160.1	2,635	159.8	3,165	158.2
	25	0.78	22.06	20.50	162.7	152	2,755	172.2	2,835	171.9	3,405	170.3
	26	0.84	22.06	20.38	174.7	152	2,945	184.2	3,035	184.0	3,645	182.3
	27	0.91	22.06	20.24	188.7	152	3,170	198.2	3,265	198.0	3,925	196.3
	28	0.98	22.06	20.10	202.5	171	3,410	213.2	3,510	212.8	4,220	211.0
24	21	0.63	25.80	24.54	155.4	171	2,655	166.0	2,735	165.8	3,280	164.0
	22	0.68	25.80	24.44	167.4	171	2,850	178.1	2,935	177.8	3,520	176.0
	23	0.73	25.80	24.34	179.4	171	3,040	190.1	3,130	189.8	3,760	188.0
	24	0.79	25.80	24.22	193.7	191	3,290	205.6	3,385	205.3	4,065	203.2
	25	0.85	25.80	24.10	207.9	191	3,515	219.8	3,620	219.5	4,350	217.4
	26	0.92	25.80	23.96	224.4	191	3,780	236.3	3,895	236.0	4,680	234.0
	21	0.63	26.32	25.06	158.6	174	2,710	169.5	2,790	169.1	3,345	167.3
	22	0.68	26.32	24.96	170.9	174	2,910	181.8	2,995	181.4	3,590	179.6
	23	0.73	26.32	24.86	183.1	174	3,105	194.0	3,195	193.6	3,835	191.8
	24	0.79	26.32	24.74	197.7	194	3,355	209.8	3,455	209.5	4,150	207.4
	25	0.85	26.32	24.62	212.2	194	3,590	224.3	3,695	224.0	4,440	221.9
	26	0.92	26.32	24.48	229.0	194	3,860	241.1	3,970	240.7	4,775	238.7
	27	0.99	26.32	24.34	245.8	221	4,155	259.6	4,275	259.2	5,135	256.8
	28	1.07	26.32	24.18	264.8	221	4,460	278.6	4,590	278.2	5,515	275.8
30	21	0.73	32.00	30.54	223.7	254	3,835	239.6	3,945	239.1	4,730	236.4
	22	0.79	32.00	30.42	241.7	254	4,120	257.6	4,240	257.1	5,090	254.4
	23	0.85	32.00	30.30	259.5	254	4,405	275.4	4,535	274.9	5,445	272.2
	24	0.92	32.00	30.16	280.3	280	4,765	297.8	4,905	297.3	5,885	294.3
	25	0.99	32.00	30.02	300.9	280	5,095	318.4	5,245	317.9	6,300	314.9
	26	1.07	32.00	29.86	324.4	280	5,470	341.9	5,635	341.4	6,770	338.4
	27	1.16	32.00	29.68	350.7	318	5,930	370.6	6,105	370.0	7,330	366.6

* Including bell and spigot bead. Calculated weight of pipe rounded off to nearest 5 lb.
† Average weight per foot based on calculated weight of pipe before rounding.

TABLE 8.2 (contd.)

STANDARD THICKNESSES, DIAMETERS AND WEIGHTS OF PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS

Nom. Diam. *in.*	Thickness Class	Thickness *in.*	Outside Diam. *in.*	Inside Diam. *in.*	Weight of Barrel per Foot *lb*	Weight of Bell and Spigot Bead *lb*	Weight (*lb*) Based on					
							16-ft Laying Length		16½-ft Laying Length		20-ft Laying Length	
							Per Length*	Avg. per Foot†	Per Length*	Avg. per Foot†	Per Length*	Avg. per Foot†
36	21	0.81	38.30	36.68	297.7	347	5,110	319.4				
	22	0.87	38.30	36.56	319.2	347	5,455	340.9				
	23	0.94	38.30	36.42	344.2	347	5,855	365.9				
	24	1.02	38.30	36.26	372.7	390	6,355	397.1				
	25	1.10	38.30	36.10	401.1	390	6,810	425.5				
	26	1.19	38.30	35.92	432.9	390	7,315	457.3				
	27	1.29	38.30	35.72	468.0	445	7,935	495.8				
	28	1.39	38.30	35.52	502.9	445	8,490	530.7				
42	21	0.90	44.50	42.70	384.6	450	6,605	412.7				
	22	0.97	44.50	42.56	413.9	450	7,070	442.0				
	23	1.05	44.50	42.40	447.2	450	7,605	475.3				
	24	1.13	44.50	42.24	480.4	510	8,195	512.3				
	25	1.22	44.50	42.06	517.6	510	8,790	549.5				
	26	1.32	44.50	41.86	558.7	510	9,450	590.6				
	27	1.43	44.50	41.64	603.7	585	10,245	640.3				
	28	1.54	44.50	41.42	648.5	585	10,960	685.1				
48	21	0.98	50.80	48.84	478.6	556	8,215	513.4				
	22	1.06	50.80	48.68	516.8	556	8,825	551.6				
	23	1.14	50.80	48.52	554.9	556	9,435	589.6				
	24	1.23	50.80	48.34	597.6	634	10,195	637.2				
	25	1.33	50.80	48.14	644.9	634	10,950	684.5				
	26	1.44	50.80	47.92	696.7	634	11,780	736.3				
	27	1.56	50.80	47.68	752.9	735	12,780	798.8				
	28	1.68	50.80	47.44	808.9	735	13,675	854.8				

* Including bell and spigot bead. Calculated weight of pipe rounded off to nearest 5 lb.
† Average weight per foot based on calculated weight of pipe before rounding.

TABLE 8.3—STANDARD THICKNESSES AND WEIGHTS OF PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS

These thicknesses and weights are for pipe laid without blocks, on flat-bottom trench, with tamped backfill, under 5 ft of cover. For other conditions see Tables 8.2 and 8.4 hereof and ASA A21.1 (AWWA C101), "Manual for the Computation of Strength and Thickness of Cast Iron Pipe."

Size *in.*	Thickness *in.*	Outside Diam. *in.*	Weight (*lb*) Based on					
			16-ft Laying Length		16½-ft Laying Length		20-ft Laying Length	
			Avg. per Foot*	Per Length†	Avg. per Foot*	Per Length†	Avg. per Foot*	Per Length†
Class 50—50-psi Pressure—115-ft Head								
3	0.32	3.96	12.4	195	12.3	205		
4	0.35	4.80	16.5	265	16.4	270		
6	0.38	6.90	25.9	415	25.8	425		
8	0.41	9.05	37.0	590	36.9	610		
10	0.44	11.10	49.1	785	49.0	810		
12	0.48	13.20	63.7	1,020	63.6	1,050	63.0	1,260
14	0.48	15.30	74.6	1,195	74.5	1,230	73.7	1,475
16	0.54	17.40	95.2	1,525	95.0	1,570	94.0	1,880
18	0.54	19.50	107.6	1,720	107.4	1,770	106.2	2,125
20	0.57	21.60	125.9	2,015	125.7	2,075	124.2	2,485
24	0.63	25.80	166.0	2,655	165.8	2,735	164.0	3,280
30	0.79	32.00	257.6	4,120	257.1	4,240	254.4	5,090
36	0.87	38.30	340.9	5,455				
42	0.97	44.50	442.0	7,070				
48	1.06	50.80	551.6	8,825				
Class 100—100-psi Pressure—231-ft Head								
3	0.32	3.96	12.4	195	12.3	205		
4	0.35	4.80	16.5	265	16.4	270		
6	0.38	6.90	25.9	415	25.8	425		
8	0.41	9.05	37.0	590	36.9	610		
10	0.44	11.10	49.1	785	49.0	810		
12	0.48	13.20	63.7	1,020	63.6	1,050	63.0	1,260
14	0.51	15.30	78.8	1,260	78.7	1,300	77.8	1,555
16	0.54	17.40	95.2	1,525	95.0	1,570	94.0	1,880
18	0.58	19.50	114.8	1,835	114.6	1,890	113.3	2,265
20	0.62	21.60	135.9	2,175	135.7	2,240	134.2	2,685
24	0.68	25.80	178.1	2,850	177.8	2,935	176.0	3,520
30	0.79	32.00	257.6	4,120	257.1	4,240	254.4	5,090
36	0.87	38.30	340.9	5,455				
42	0.97	44.50	442.0	7,070				
48	1.06	50.80	551.6	8,825				
Class 150—150-psi Pressure—346-ft Head								
3	0.32	3.96	12.4	195	12.3	205		
4	0.35	4.80	16.5	265	16.4	270		
6	0.38	6.90	25.9	415	25.8	425		
8	0.41	9.05	37.0	590	36.9	610		
10	0.44	11.10	49.1	785	49.0	810		
12	0.48	13.20	63.7	1,020	63.6	1,050	63.0	1,260
14	0.51	15.65	80.7	1,290	80.5	1,330	79.7	1,595
16	0.54	17.80	97.5	1,560	97.3	1,605	96.3	1,925
18	0.58	19.92	117.2	1,875	117.0	1,930	115.8	2,315
20	0.62	22.06	138.9	2,220	138.6	2,285	137.2	2,745
24	0.73	26.32	194.0	3,105	193.6	3,195	191.8	3,835
30	0.85	32.00	275.4	4,405	274.9	4,535	272.2	5,445
36	0.94	38.30	365.9	5,855				
42	1.05	44.50	475.3	7,605				
48	1.14	50.80	589.6	9,435				

* Average weight per foot based on calculated weight of pipe before rounding
† Including bell and spigot bead. Calculated weight of pipe rounded off to nearest 5 lb.

TABLE 8.3 (contd.)—STANDARD THICKNESSES AND WEIGHTS

Size *in.*	Thickness *in.*	Outside Diam. *in.*	Weight (*lb*) Based on					
			16-ft Laying Length		16½-ft Laying Length		20-ft Laying Length	
			Avg. per Foot*	Per Length†	Avg. per Foot*	Per Length†	Avg. per Foot*	Per Length†
Class 200—200-psi Pressure—462-ft Head								
3	0.32	3.96	12.4	195	12.3	205		
4	0.35	4.80	16.5	265	16.4	270		
6	0.38	6.90	25.9	415	25.8	425		
8	0.41	9.05	37.0	590	36.9	610		
10	0.44	11.10	49.1	785	49.0	810		
12	0.48	13.20	63.7	1,020	63.6	1,050	63.0	1,260
14	0.55	15.65	86.4	1,380	86.3	1,425	85.4	1,710
16	0.58	17.80	104.0	1,665	103.8	1,715	102.8	2,055
18	0.63	19.92	126.5	2,025	126.2	2,080	125.0	2,500
20	0.67	22.06	149.1	2,385	148.8	2,455	147.3	2,945
24	0.79	26.32	209.8	3,355	209.5	3,455	207.4	4,150
30	0.92	32.00	297.8	4,765	297.3	4,905	294.3	5,885
36	1.02	38.30	397.1	6,355				
42	1.13	44.50	512.3	8,195				
48	1.23	50.80	637.2	10,195				
Class 250—250-psi Pressure—577-ft Head								
3	0.32	3.96	12.4	195	12.3	205		
4	0.35	4.80	16.5	265	16.4	270		
6	0.38	6.90	25.9	415	25.8	425		
8	0.41	9.05	37.0	590	36.9	610		
10	0.44	11.10	49.1	785	49.0	810		
12	0.52	13.20	68.5	1,095	68.4	1,130	67.8	1,355
14	0.59	15.65	92.7	1,485	92.5	1,525	91.5	1,830
16	0.63	17.80	112.9	1,805	112.7	1,860	111.4	2,230
18	0.68	19.92	136.3	2,180	136.1	2,245	134.7	2,695
20	0.72	22.06	160.1	2,560	159.8	2,635	158.2	3,165
24	0.79	26.32	209.8	3,355	209.5	3,455	207.4	4,150
30	0.99	32.00	318.4	5,095	317.9	5,245	314.9	6,300
36	1.10	38.30	425.5	6,810				
42	1.22	44.50	549.5	8,790				
48	1.33	50.80	684.5	10,950				
Class 300—300-psi Pressure—693-ft Head								
3	0.32	3.96	12.4	195	12.3	205		
4	0.35	4.80	16.5	265	16.4	270		
6	0.38	6.90	25.9	415	25.8	425		
8	0.41	9.05	37.0	590	36.9	610		
10	0.48	11.10	53.1	850	53.0	875		
12	0.52	13.20	68.5	1,095	68.4	1,130	67.8	1,355
14	0.59	15.65	92.7	1,485	92.5	1,525	91.5	1,830
16	0.68	17.80	121.0	1,935	120.8	1,995	119.4	2,390
18	0.73	19.92	145.4	2,325	145.2	2,395	143.7	2,875
20	0.78	22.06	172.2	2,755	171.9	2,835	170.3	3,405
24	0.85	26.32	224.3	3,590	224.0	3,695	221.9	4,440
Class 350—350-psi Pressure—808-ft Head								
3	0.32	3.96	12.4	195	12.3	205		
4	0.35	4.80	16.5	265	16.4	270		
6	0.38	6.90	25.9	415	25.8	425		
8	0.41	9.05	37.0	590	36.9	610		
10	0.52	11.10	57.4	920	57.3	945		
12	0.56	13.20	73.8	1,180	73.7	1,215	73.0	1,460
14	0.64	15.65	99.8	1,595	99.7	1,645	98.7	1,975
16	0.68	17.80	121.0	1,935	120.8	1,995	119.4	2,390
18	0.79	19.92	156.2	2,500	156.1	2,575	154.6	3,090
20	0.84	22.06	184.2	2,945	184.0	3,035	182.3	3,645
24	0.92	26.32	241.1	3,860	240.7	3,970	238.7	4,775

*† See footnotes on preceding page.

TABLE 8.4

STANDARD THICKNESSES* OF PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS

Laying Condition A—Flat-bottom trench, without blocks, untamped backfill
Laying Condition B—Flat-bottom trench, without blocks, tamped backfill
Laying Condition C—Pipe laid on blocks, untamped backfill
Laying Condition D—Pipe laid on blocks, tamped backfill

Size *in.*	Working Pressure *psi*	3½-ft Cover				5-ft Cover				8-ft Cover			
		Laying Condition				Laying Condition				Laying Condition			
		A	B	C	D	A	B	C	D	A	B	C	D
		Thickness—*in.*											
3	50	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.38	0.32
	100	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.38	0.32
	150	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.38	0.32
	200	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.38	0.32
	250	0.32	0.32	0.32	0.32	0.32	0.32	0.35	0.32	0.32	0.32	0.38	0.32
	300	0.32	0.32	0.32	0.32	0.32	0.32	0.35	0.32	0.32	0.32	0.38	0.32
	350	0.32	0.32	0.32	0.32	0.32	0.32	0.35	0.32	0.32	0.32	0.38	0.32
4	50	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.41	0.35
	100	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.41	0.35
	150	0.35	0.35	0.35	0.35	0.35	0.35	0.38	0.35	0.35	0.35	0.41	0.35
	200	0.35	0.35	0.35	0.35	0.35	0.35	0.38	0.35	0.35	0.35	0.44	0.35
	250	0.35	0.35	0.35	0.35	0.35	0.35	0.38	0.35	0.35	0.35	0.44	0.35
	300	0.35	0.35	0.35	0.35	0.35	0.35	0.38	0.35	0.35	0.35	0.44	0.35
	350	0.35	0.35	0.38	0.35	0.35	0.35	0.38	0.35	0.35	0.35	0.44	0.35
6	50	0.38	0.38	0.41	0.38	0.38	0.38	0.44	0.38	0.38	0.38	0.48	0.38
	100	0.38	0.38	0.41	0.38	0.38	0.38	0.44	0.38	0.38	0.38	0.48	0.38
	150	0.38	0.38	0.41	0.38	0.38	0.38	0.44	0.38	0.38	0.38	0.48	0.38
	200	0.38	0.38	0.41	0.38	0.38	0.38	0.44	0.38	0.38	0.38	0.52	0.38
	250	0.38	0.38	0.44	0.38	0.38	0.38	0.44	0.38	0.38	0.38	0.52	0.38
	300	0.38	0.38	0.44	0.38	0.38	0.38	0.44	0.38	0.38	0.38	0.52	0.38
	350	0.38	0.38	0.44	0.38	0.38	0.38	0.48	0.38	0.38	0.38	0.52	0.38
8	50	0.41	0.41	0.44	0.41	0.41	0.41	0.48	0.41	0.41	0.41	0.52	0.41
	100	0.41	0.41	0.48	0.41	0.41	0.41	0.48	0.41	0.41	0.41	0.56	0.41
	150	0.41	0.41	0.48	0.41	0.41	0.41	0.48	0.41	0.41	0.41	0.56	0.41
	200	0.41	0.41	0.48	0.41	0.41	0.41	0.52	0.41	0.41	0.41	0.56	0.44
	250	0.41	0.41	0.48	0.41	0.41	0.41	0.52	0.41	0.44	0.41	0.56	0.44
	300	0.41	0.41	0.48	0.41	0.41	0.41	0.52	0.41	0.44	0.44	0.60	0.44
	350	0.41	0.41	0.52	0.41	0.44	0.41	0.52	0.44	0.48	0.44	0.60	0.48
10	50	0.44	0.44	0.48	0.44	0.44	0.44	0.52	0.44	0.44	0.44	0.60	0.48
	100	0.44	0.44	0.52	0.44	0.44	0.44	0.52	0.44	0.48	0.44	0.60	0.48
	150	0.44	0.44	0.52	0.44	0.44	0.44	0.56	0.44	0.48	0.44	0.60	0.48
	200	0.44	0.44	0.52	0.44	0.44	0.44	0.56	0.44	0.48	0.48	0.60	0.52
	250	0.44	0.44	0.56	0.44	0.48	0.44	0.56	0.48	0.52	0.48	0.65	0.52
	300	0.48	0.44	0.56	0.48	0.48	0.48	0.56	0.48	0.52	0.52	0.65	0.56
	350	0.48	0.48	0.56	0.48	0.52	0.52	0.60	0.52	0.56	0.52	0.65	0.56
12	50	0.48	0.48	0.52	0.48	0.48	0.48	0.56	0.48	0.52	0.48	0.65	0.52
	100	0.48	0.48	0.56	0.48	0.48	0.48	0.56	0.48	0.52	0.48	0.65	0.52
	150	0.48	0.48	0.56	0.48	0.48	0.48	0.56	0.48	0.52	0.52	0.65	0.56
	200	0.48	0.48	0.56	0.48	0.48	0.48	0.60	0.52	0.56	0.52	0.65	0.56
	250	0.52	0.48	0.60	0.52	0.52	0.52	0.60	0.52	0.56	0.56	0.70	0.60
	300	0.52	0.52	0.60	0.52	0.56	0.52	0.60	0.56	0.60	0.56	0.70	0.60
	350	0.56	0.56	0.60	0.56	0.56	0.56	0.65	0.60	0.60	0.60	0.76	0.65
14	50	0.51	0.48	0.59	0.51	0.51	0.48	0.59	0.55	0.59	0.55	0.69	0.59
	100	0.51	0.48	0.59	0.55	0.55	0.51	0.64	0.55	0.59	0.55	0.69	0.64
	150	0.55	0.51	0.59	0.55	0.55	0.51	0.64	0.59	0.64	0.59	0.75	0.64
	200	0.55	0.51	0.64	0.59	0.55	0.55	0.64	0.59	0.64	0.59	0.75	0.69
	250	0.59	0.55	0.64	0.59	0.59	0.59	0.69	0.59	0.64	0.64	0.75	0.69
	300	0.59	0.59	0.69	0.59	0.64	0.59	0.69	0.64	0.69	0.64	0.81	0.69
	350	0.64	0.64	0.69	0.64	0.64	0.64	0.75	0.69	0.75	0.69	0.81	0.75

* Thicknesses include allowances for foundry practice, corrosion, and either water hammer or truck load.

TABLE 8.4 (contd.)

STANDARD THICKNESSES* OF PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS

Laying Condition A—Flat-bottom trench, without blocks, untamped backfill
Laying Condition B—Flat-bottom trench, without blocks, tamped backfill
Laying Condition C—Pipe laid on blocks, untamped backfill
Laying Condition D—Pipe laid on blocks, tamped backfill

Size in.	Working Pressure psi	3½-ft Cover				5-ft Cover				8-ft Cover			
		Laying Condition				Laying Condition				Laying Condition			
		A	B	C	D	A	B	C	D	A	B	C	D
		Thickness—in.											
16	50	0.54	0.50	0.63	0.58	0.58	0.54	0.63	0.58	0.63	0.58	0.73	0.63
	100	0.54	0.54	0.63	0.58	0.58	0.54	0.68	0.58	0.63	0.58	0.73	0.68
	150	0.58	0.54	0.63	0.58	0.58	0.54	0.68	0.63	0.68	0.63	0.79	0.68
	200	0.58	0.58	0.68	0.63	0.63	0.58	0.68	0.63	0.68	0.63	0.79	0.73
	250	0.63	0.58	0.68	0.63	0.63	0.63	0.73	0.68	0.73	0.68	0.79	0.73
	300	0.63	0.63	0.73	0.68	0.68	0.68	0.73	0.68	0.73	0.73	0.85	0.79
	350	0.68	0.68	0.73	0.68	0.73	0.68	0.79	0.73	0.79	0.73	0.85	0.79
18	50	0.58	0.54	0.63	0.58	0.58	0.54	0.68	0.63	0.68	0.63	0.79	0.68
	100	0.58	0.54	0.68	0.63	0.63	0.58	0.73	0.63	0.68	0.63	0.79	0.73
	150	0.63	0.58	0.68	0.63	0.63	0.58	0.73	0.68	0.73	0.68	0.79	0.73
	200	0.63	0.58	0.73	0.68	0.68	0.63	0.73	0.68	0.73	0.68	0.85	0.79
	250	0.68	0.63	0.73	0.68	0.68	0.68	0.79	0.73	0.79	0.73	0.85	0.79
	300	0.68	0.68	0.79	0.73	0.73	0.73	0.79	0.79	0.79	0.79	0.92	0.85
	350	0.79	0.73	0.79	0.79	0.79	0.79	0.85	0.79	0.85	0.85	0.92	0.85
20	50	0.62	0.57	0.72	0.62	0.67	0.57	0.72	0.67	0.72	0.67	0.78	0.72
	100	0.62	0.57	0.72	0.67	0.67	0.62	0.78	0.67	0.72	0.67	0.84	0.78
	150	0.67	0.62	0.72	0.67	0.67	0.62	0.78	0.72	0.78	0.72	0.84	0.78
	200	0.67	0.62	0.78	0.72	0.72	0.67	0.78	0.72	0.78	0.72	0.91	0.84
	250	0.72	0.67	0.78	0.72	0.78	0.72	0.84	0.78	0.84	0.78	0.91	0.84
	300	0.78	0.72	0.84	0.78	0.78	0.78	0.84	0.84	0.84	0.84	0.98	0.91
	350	0.84	0.78	0.84	0.84	0.84	0.84	0.91	0.84	0.91	0.84	0.98	0.91
24	50	0.68	0.63	0.79	0.68	0.73	0.63	0.79	0.73	0.79	0.73	0.85	0.79
	100	0.73	0.63	0.79	0.73	0.73	0.68	0.85	0.79	0.85	0.73	0.92	0.85
	150	0.73	0.68	0.79	0.79	0.79	0.73	0.85	0.79	0.85	0.79	0.92	0.85
	200	0.79	0.73	0.85	0.79	0.79	0.79	0.92	0.85	0.92	0.85	0.99	0.92
	250	0.79	0.79	0.85	0.85	0.85	0.79	0.92	0.85	0.92	0.85	0.99	0.99
	300	0.85	0.85	0.92	0.85	0.92	0.85	0.99	0.92	0.99	0.92	1.07	0.99
	350	0.92	0.92	0.99	0.92	0.99	0.92	0.99	0.99	1.07	0.99	1.07	1.07
30	50	0.85	0.73	0.85	0.85	0.85	0.79	0.92	0.85	0.92	0.85	0.99	0.92
	100	0.85	0.79	0.92	0.85	0.92	0.79	0.99	0.92	0.99	0.85	1.07	0.99
	150	0.92	0.79	0.92	0.92	0.92	0.85	0.99	0.92	0.99	0.92	1.07	0.99
	200	0.92	0.85	0.99	0.92	0.99	0.92	1.07	0.99	1.07	0.99	1.16	1.07
	250	0.99	0.92	1.07	0.99	1.07	0.99	1.07	1.07	1.16	1.07	1.16	1.16
36	50	0.94	0.81	1.02	0.94	1.02	0.87	1.10	0.94	1.10	0.94	1.19	1.02
	100	0.94	0.87	1.02	0.94	1.02	0.87	1.10	1.02	1.10	1.02	1.19	1.10
	150	1.02	0.87	1.10	1.02	1.10	0.94	1.10	1.02	1.19	1.02	1.19	1.19
	200	1.10	0.94	1.10	1.02	1.10	1.02	1.19	1.10	1.19	1.10	1.29	1.19
	250	1.10	1.02	1.19	1.10	1.19	1.10	1.29	1.19	1.29	1.19	1.39	1.29
42	50	1.05	0.90	1.13	1.05	1.13	0.97	1.13	1.05	1.22	1.05	1.32	1.13
	100	1.05	0.97	1.13	1.05	1.13	0.97	1.22	1.13	1.22	1.13	1.32	1.22
	150	1.13	0.97	1.22	1.13	1.22	1.05	1.22	1.13	1.32	1.13	1.32	1.32
	200	1.22	1.05	1.22	1.13	1.22	1.13	1.32	1.22	1.32	1.22	1.43	1.32
	250	1.32	1.13	1.32	1.22	1.32	1.22	1.43	1.32	1.43	1.32	1.54	1.43
48	50	1.14	0.98	1.23	1.14	1.23	1.06	1.33	1.14	1.33	1.14	1.44	1.33
	100	1.23	1.06	1.23	1.14	1.23	1.06	1.33	1.23	1.33	1.23	1.44	1.33
	150	1.23	1.14	1.33	1.23	1.33	1.14	1.44	1.33	1.44	1.33	1.56	1.44
	200	1.33	1.14	1.44	1.33	1.44	1.23	1.44	1.33	1.56	1.33	1.56	1.44
	250	1.44	1.33	1.44	1.33	1.44	1.33	1.56	1.44	1.56	1.44	1.68	1.56

* Thicknesses include allowances for foundry practice, corrosion, and either water hammer or truck load.

AWWA C502-53
(Formerly 7F.3)

American Water Works Association

New England Water Works Association

Standard Specifications

for

FIRE HYDRANTS FOR ORDINARY WATER WORKS SERVICE

The American Water Works Association and the New England Water Works Association have adopted and promulgated these basic "Standard Specifications for Fire Hydrants for Ordinary Water Works Service." They are based upon the best known experience and are intended for use under normal conditions. They are not designed for unqualified use under all conditions and the advisability of use of the material herein specified for any installation must be subjected to review by the engineer responsible for the construction in the particular locality concerned.

Approved as revised by AWWA Mar. 16, 1953; by NEWWA June 18, 1953

First Edition: 7F.3–1940 (C502–40); Revised Edition: C502–53

AMERICAN WATER WORKS ASSOCIATION
Incorporated
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NOTE: All references to standards of AWWA or other technical societies or of the federal government within these specifications are to the latest revisions, including amendments, of the documents involved. The date keys on standards of AWWA and other technical societies have been omitted to avoid early obsolescence of such references.

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Foreword

These specifications supersede the document first published as "Tentative" in the April 1937 JOURNAL; revised June 1937, August 1938, and January 1940; and published in the August 1940 JOURNAL as "Standard." They are jointly sponsored and promulgated by AWWA and NEWWA.

The revision committee, with R. W. Esty as chairman and R. C. Dennett, R. H. Ellis, H. W. Griswold, L. A. Jackson, R. C. Kennedy, and E. E. Norman as the other members, was appointed in 1944 and charged with the duty of reviewing and revising the 1940 text. This committee filed its report on Dec. 30, 1948. Action upon that report was deferred and discussions of the proposed revisions have been held at various times since. The document was completely rearranged and sent out for review on Sept. 6, 1951. The comments received at that time were taken into account and a text (further revised) was circulated as of Apr. 15, 1952. Following discussions of this draft at the 1952 Conference of AWWA, by direction of the Board of AWWA, an ad hoc task group, consisting of C. H. Capen, R. H. Ellis, H. F. O'Brien, C. H. Simon, and H. E. Jordan, was authorized to develop a consensus and put the text into routine process for approval by the two Associations—AWWA and NEWWA. The text as agreed upon by the special committee was again submitted to the AWWA Board of Directors on Feb. 10, 1953, and was approved by it on Mar. 16, 1953.

These specifications become effective as a basis for purchase Sept. 1, 1953.

The fire hydrant is a unit of water utility property provided for service to the public in an emergency but is operated in such an emergency by firemen—not by water utility employees.

The use of fire hydrants by street-cleaning or sprinkling personnel, by workers on construction projects, and sometimes by city employees to provide mid-summer recreation for children is beyond the primary purpose of fire fighting for which the units are installed. Such irregular uses of hydrants must be rigidly restricted and controlled by the water utility in the interest of keeping the equipment in good working order for use at times of fire.

The water utility, unless expressly relieved by the fire department in accordance with a written agreement or public ordinance, must schedule regular and frequent inspection of hydrants and keep them in good working condition.

Hydrants produced according to these specifications are designed to be operated by one man with a 15-in. wrench—not with a 24-in. wrench nor with an indefinite extender which two or more men handle. If one man using a 15-in. wrench cannot open and close a fire hydrant, it is not in proper working order and should be promptly put in good condition.

In areas where severe winter conditions exist, it is the responsibility of the water utility to see that water does not get into the hydrant barrel and freeze. In some states, health authorities forbid the installation of hydrants with drain valves. In such circumstances, the utility personnel are doubly responsible for maintaining the hydrant operating valve in such good order that water will not leak into the barrel from the main, stand there, and freeze.

Hydrants produced under these specifications are required to meet a test of 200-ft-lb torque applied at the operating nut in both opening and closing directions. This torque is considered fully adequate to operate a hydrant which is in good working condition. Hyrants with barrels longer than 5-ft bury may, however, require special design.

Appended to these specifications are: a tabulation giving the characteristics of the ASA B26 Standard for Fire-Hose Coupling Screw Thread; and the *optional* Specifications for Uniform Marking of Fire Hydrants—AWWA C503 (formerly 7F.3.1).

Standard Specifications for

Fire Hydrants for Ordinary Water Works Service

Sec. 1—Type of Hydrant and Character of Service

1.1. These specifications embrace the various types and classes of hydrants for general water works service. The items described are the various forms of post hydrants with compression (working against or with the pressure) or gate type of shutoff.

1.2. Hydrants shall be designed for a working pressure of 150 psi.

1.3. Hydrants of special design, including those having built-in hose gates, and hydrants designed for higher working pressure are not covered.

1.4. Hydrants which have replaceable "breakable" sections or components are not explicitly covered in later sections of these specifications. It is stipulated, however, that such hydrants shall conform to these specifications in all details except the special bolts or sections which intentionally have a lower breaking point than the rest of the unit.

1.5. These specifications do not cover the wet-barrel or "California" type of hydrant.

1.6. References to the setting and drainage of hydrants are not included in these specifications. For installation standards, see Specifications for Installation of Cast-Iron Water Mains —AWWA C600.

Sec. 2—Supplementary Details to Be Specified

When hydrants are to be purchased under these specifications, the purchaser shall provide specific supplementary information concerning the following details:

2.1. *Type of shutoff*—compression or gate.

2.2. *Inlet connection, size, and type* —bell, flange, or other.

2.3. *Delivery classification*—designated according to the number of hose and pumper nozzles; for example: "two-hose nozzle," "one-pumper nozzle," "one-hose and one-pumper nozzle," "three-hose nozzle," "two-hose and one-pumper nozzle," "three-hose and one-pumper nozzle," "four-hose nozzle," "two-pumper nozzle."

2.4. *Bury length*—in feet (to the nearest $\frac{1}{2}$ ft), measured from the bottom of the connecting pipe to the ground line at the hydrant.

2.5. *Diameter (nominal inside) of hose nozzles and pumper nozzle, if any* —in inches.

2.6. *Hose and pumper nozzle threads* —if in conformity with ASA specifications B26 for "National (American) Standard Fire-Hose Coupling Screw Thread," so specify. If not ASA standard thread, specify the following details or supply a sample:

Outside diameter of male thread finished
Diameter of root of male thread
Number of threads per inch
Pattern of thread
Cut off....in. at top of thread
Leave....in. in bottom of valley.

2.7. *Harnessing lugs*—if required (see Sec. 5.9).

2.8. *Nozzle cap gasket*—if required.

2.9. *Tapping of drain opening to receive threaded pipe*—if required.

2.10. *If hydrant is to be made without drain opening, so specify.*

2.11. *Direction to open*—right (clockwise) or left (counterclockwise).

2.12. *Color of finish paint above ground line.*

2.13. *Shape and size of operating and cap nuts*—see Sec. 5.19.

Sec. 3—Data to Be Furnished by Manufacturer

3.1. After purchase, the manufacturer shall, if requested, furnish catalog data (including illustrations and a schedule of parts and the materials of which they are made) in sufficient detail to serve as a guide in the assembly and taking down of the hydrant, as well as in ordering repair parts.

3.2. When required, the manufacturer shall furnish a statement giving the total net assembled weight of each size of hydrant ordered.

3.3. When required, the manufacturer shall submit, without charge, one set of certified drawings of all parts showing the principal dimensions, construction details, materials used, and the finish thereof, for approval by the purchaser. When approved, no work shall be done or hydrants furnished that are not in accordance with the approved drawings.

Sec. 4—Materials

4.1. *General.* All materials designated hereinafter shall, when used in hydrants produced under these specifications, conform to the specifications designated below for each material listed. When reference is made to ASA, ASTM, or other specifications, it is understood that the latest revision thereof shall apply.

4.2. *Physical and chemical properties of components.* The requirements of ASA, ASTM, or other standard specifications to which reference is made elsewhere in this text shall govern the physical and chemical characteristics of the hydrant components.

4.3. *Standard test procedures for components.* Whenever hydrant components are to be made in conformance with ASA, ASTM, or other specifications, all test requirements or testing procedures specified therein shall be met by the hydrant manufacturer. The records of such tests shall, if required by the purchaser, be made available to him.

4.4. *Cast iron.* All cast iron shall conform to ASTM specifications A126 Class B (Gray Iron Castings for Valves, Flanges, and Pipe Fittings).

4.5. *Wrought iron.* When wrought iron is used, it shall conform to ASTM A84 (Staybolt Wrought Iron).

4.6. *Steel.* Steel shall conform to ASTM A107 (Hot-Rolled Carbon-Steel Bars).

4.7. *Brass or bronze.* Hydrant components made from brass or bronze shall be one of six grades:

Grade I—conforming to ASTM B62

Grade II—conforming to ASTM B132 (Alloy A)

Grade III—conforming to ASTM B132 (Alloy B), B98 (Type D—hard), or B150 (Alloy 1)

Grade IV—rolled bronze (naval brass) conforming to ASTM B21 (Alloy A, one-half hard)

Grade V—conforming to ASTM B147 (Grade 8a)

Grade VI—conforming to ASTM B124 (Grade 2).

4.8. *Bolt and nuts:*

4.8.1. Body bolts and nuts shall conform to ASTM A307 (Grade B). Bolts and nuts shall be either cadmium

plated or zinc coated (ASTM A123), or rustproofed by some other process (Parkerizing, Sherardizing, or the like) disclosed to and acceptable to the purchaser. Body bolt studs shall conform to the physical and threading requirements of ASTM A307 (Grade B).

4.8.2. Gland bolts may be made of either Grade II, III, or IV bronze or rustproofed steel in accordance with Sec. 4.8.1 of these specifications. Gland bolt nuts shall be made of Grade II, III, or IV bronze.

4.8.3. Stuffing box bolts and nuts shall conform to Sec. 4.8.1 above; *or*, if bronze is used, it shall be Grade II, III, IV, or V.

4.9. *Packing.* Stuffing box packing shall be made of asbestos conforming to Navy Department Specification 33–P–26–b (Type A) or flax conforming to Federal Specification HH–P–106c; or O ring seal may be used. Hemp packing shall not be used.

4.10. *Gaskets.* Gasket material shall be sheet asbestos, rubber composition, or paper free from corrosive ingredients, either alkaline or acid.

4.11. *Paint.* Paint used in coating the hydrant as required by Sec. 6.1 shall conform to the requirements of Federal Specification TT–V–51a asphalt varnish or Army-Navy Specification JAN–P–450. Exterior coating above the ground line (Sec. 6.2) shall conform to Federal Specification TT–P–86a (Type IV), *unless otherwise specified by the purchaser.*

Sec. 5—Design

5.1. *Iron and bronze—where used:*

5.1.1. *Parts of cast iron.* The parts where cast iron may be used are the footpiece or elbow, the barrel or standpipe, the frost jacket if used, the bonnet, the packing plate, the gates, the nozzle caps, and small miscellaneous parts where the use of cast iron will conform to good practice.

5.1.2. *Parts of bronze.* The parts where bronze is used are:

Parts	Refer to Sec.	Grade of Bronze
Drain valve parts	5.17	I, II, III, IV, VI
Glands	5.21	I, II, III, IV, VI
Gland bolts	5.21	II, III, IV
Gland bolt nuts	5.21	II, III, IV
Gland bushings	5.21	I
Nozzles	5.10	I
Stems or threaded portion of stems	5.15.1	II, III, IV, V
Stem nuts	5.15.1	I, II, III
Stuffing boxes	5.21	I
Stuffing box bolts and nuts	4.8.3	II, III, IV, V
Valve seats or valve seat rings	5.14	I, II, III, IV

Reference should be made to the sections of this document where the above components are detailed. In several instances, ferrous metal, properly treated, may be used instead of bronze.

5.2. *Size of hydrant valve.* The main valve opening shall be at least 4 in. in diameter for hydrants having two 2½-in. nozzles; at least 5 in. for hydrants having three 2½-in. nozzles; and at least 6 in. for hydrants having four 2½-in. nozzles. With other than circular seat rings, the area of the seat ring opening shall equal that of the above required circular seat ring. Any seat ring diameter offered other than those enumerated shall be considered equal to the next smaller size as specified above.

Combinations of nozzles other than those above are permissible, provided that the total potential discharge capacity of such nozzle combination connected to the main valve does not exceed the maximum discharge capacity

of nozzles connected to a main valve of the same size in the above list.

Thus, as it is understood that hose nozzles and pumper nozzles are not in action at the same time, one pumper nozzle may be added to any of the above hose nozzle combinations, or substituted for any one or two hose nozzles; provided that the discharge area of the pumper nozzle *either*: (a) does not exceed the discharge area of the 2½-in. hose nozzle or nozzles to which it is added or for which it is substituted, *or* (b) does not exceed the discharge area of the main valve of the hydrant.

5.3. *Valve facing.* The main valve of the hydrant shall be faced with a suitable yielding material, such as rubber, leather, balata, or composition, where it bears on metal seats. The material shall be clamped so that the valve will not leak at the stem. The bottom stem threads may be protected by a suitable cap nut.

5.4. *Hydrant barrel wall thickness.* The thickness of the wall of the barrel shall be not less than the thickness specified for Class 250 pit-cast cast-iron water pipe of like diameter produced in accordance with ASA A21.2 (American Standard Specifications for Cast Iron Pit Cast Pipe for Water or Other Liquids) and Table 2.3 thereof. The wall thickness of barrels of fractional-inch diameter shall be that for the next larger diameter listed below. The specified thicknesses thus are:

Barrel ID *in.*	Wall Thickness *in.*
5	0.42*
6	0.43
7	0.46*
8	0.50
9	0.56*
10	0.63

* Values not shown in Table 2.3 of ASA A21.2 but interpolated for purposes of these specifications.

Variations in thickness of walls of hydrant barrels shall not exceed those permitted for pit-cast cast-iron pipe of like diameter as recorded in Sec. 2–11 (b) of ASA A21.2, as follows:

Nominal Diameter *in.*	Tolerance *in.*
3–8 incl.	0.07
10–24 incl.	0.08

Tolerances 0.02 in. greater than those listed above shall be permissible over areas not exceeding 8 in. in length in any direction.

5.5. *Barrel sections.* If hydrants are made in two or more sections with a flange or other joint near the ground line, the joint shall, unless otherwise specified by the purchaser, be located at least 2 in. above the finished grade line.

5.6. *Waterway.* Changes in the shape or size of the waterway shall be accomplished by means of easy curves. The junctions of hose and pumper nozzles with the barrel shall be rounded to ample radii. Exclusive of the main valve opening, the net area of the waterway of the barrel and foot-piece at the smallest part shall be not less than 120 per cent of that of the net opening of the main valve.

5.7. *Friction losses.* With the hydrant 5 ft in length, measured from the bottom of the connecting pipe to the ground line, and discharging 250 gpm through each 2½-in. hose outlet, the friction loss shall not exceed the following:

Flow *gpm*	Pressure Loss *psi*
250	1
500	2
750	3
1,000	4

5.8. *Hydrant inlet.* The base of the hydrant, known as the footpiece or elbow, shall have a side or bottom inlet, provided with a bell, a flange, or other type of connection as specified or approved by the purchaser for connecting the hydrant to the branch from the main. The inlet shall be suitable for connection to pipe of not less than 6-in. nominal diameter, unless otherwise ordered. In a hydrant provided with bell type connections, the bell dimensions shall conform to those shown in Specifications for Special Castings—AWWA C100 (Class D). In a hydrant provided with flange type connections, the flange dimensions shall conform to ASA B16.1 (Cast Iron Pipe Flanges and Flanged Fittings, Class 125). When a hydrant is to be connected to mechanical-joint pipe, the bell dimensions shall conform to Table 11.1 of ASA A21.11 (American Standard Specifications for a Mechanical Joint for Cast Iron Pressure Pipe and Fittings).

5.9. *Lugs.* Lugs, if required, for harnessing the hydrant to the connecting pipe from the street main shall be provided on the bell of the elbow.

5.10. *Joining nozzles to barrel.* Hose nozzles shall be of Grade I bronze and shall be fastened into the barrel by a fine thread or by leading. If lead is used, an adequate recess shall be provided for the lead. All nozzles shall be safeguarded against blowing out. For screwed-in nozzles, a pin or other approved method shall be employed to prevent the nozzle from turning or backing out.

5.11. *Nozzle caps.* Nozzle caps shall be of cast iron and shall be provided for all outlets. The threads shall conform to those of the nozzle. The cap nut shall have dimensions similar to those of the operating nut. Unless otherwise ordered, caps shall be securely chained to the barrel with a metal chain having links made from stock not less than $\frac{1}{8}$ in. in diameter, or of equivalent cross-sectional area. A recess shall be provided at the inner end of the threads to retain a gasket.

5.12. *Valves readily removable.* The hydrant shall be so designed that, when it is in place, no excavation will be required to remove the main valve and the movable parts of the drain valve.

5.13. *Main valve remains closed after accident.* The barrel and operating mechanism shall be so designed that, in the event of accident, damage, or breaking of the hydrant above or near the grade level, the main valve will remain closed and reasonably tight against leakage.

5.14. *Valve seats.* Valve seats or seat rings shall be made of Grade I, II, III, or IV bronze.

5.15. *Operating mechanism:*

5.15.1. The operating threads of the hydrant shall be so designed as to avoid the working of any iron or steel parts against either iron or steel. Either the operating stem or its threaded stem nut (or sleeve) shall be of noncorrodible metal. If the threaded portion of the operating stem is bronze, it shall be made of Grade II, III, or IV material. If the threaded stem nut is bronze, it shall be made of Grade I, II, or III material. The operating stem and nut shall have square, V, or Acme threads. The design factor of safety of the operating mechanism shall be five, and shall be based on the foot-pounds torque required for the closing and opening of the individual hydrant at 150-psi working water pressure. Hydrants shall be capable of being opened or closed after being subjected

to an operating torque of 200 ft-lb applied at the operating nut. The torque requirements apply only to hydrants of 5-ft bury and under. (See Foreword.)

5.15.2. The operating mechanism, particularly the lead of the thread of the operating stem, shall be so designed that when the operating nut is turned at the fastest possible rate using a 15-in. wrench to shut off the flow of water, the resulting pressure in the system shall not exceed twice the static pressure if the static pressure averages 60 psi or greater. If the static pressure averages less than 60 psi, the pressure shall not be raised more than 60 psi above the static.

NOTE: As the number of complete turns of the hydrant wrench required to close the hydrant valve has a bearing upon the possibility of developing water hammer, preference is indicated for lead of the threads on the hydrant stem which requires *not less than:* 8 complete turns to close a 4-in. hydrant; 10 complete turns to close a 5-in. hydrant; and 12 complete turns to close a 6-in. hydrant.

5.16. *Drain or waste outlet.* An outlet for drainage shall be provided in the base or barrel, or between the base and barrel, of the hydrant. It shall be made of Grade I, II, III, or IV bronze (or other corrosion-resistant metal) or bushed therewith completely from the valve to the outside.

5.17. *Drain valve mechanism.* A positive-operating noncorrodible drain valve or valves shall be provided to drain the hydrant properly by opening as soon as the main valve is closed, and to close tightly when the main valve is opened. The seat of the drain valve shall be made of Grade I, II, III, IV, or VI bronze or other noncorrodible material and shall be fastened securely in the hydrant.

5.18. *Hydrant top.* The hydrant top or bonnet shall be of cast iron, and shall be free-draining and of a type that will maintain the operating mechanism in readiness to use under freezing conditions. It shall be so designed as to make tampering difficult and shall be provided with convenient means to afford lubrication to insure ease of operation and the prevention of wear and corrosion.

5.19. *Operating and cap nuts.* The operating nut and the cap nuts on the hose and pumper nozzles shall conform to those in service in the system where the hydrant is to be installed. Unless otherwise required, the nuts shall be of pentagonal shape. The pentagon shall measure $1\frac{1}{2}$ in. from point to flat at the base of the nut and $1\frac{7}{16}$ in. at the top. Faces shall be tapered uniformly, and the height of the nut shall be not less than 1 in. The point-to-flat dimension shall be measured to the theoretical point where the faces would intersect were there no rounding off of the corner. Wrenches for these nuts shall have no taper in the openings, so as to be readily reversible.

5.20. *Direction of opening.* The direction of rotation of the operating nut to open the hydrant should conform to the practice in the water system where the hydrant is to be installed. *Unless otherwise ordered* by the purchaser, the hydrant shall be opened by turning the operating nut *counterclockwise.* An arrow and the word "Open" shall be cast in relief, so as to be clearly visible, on the top of the hydrant to designate the direction of opening.

5.21. *Stuffing boxes.* Stuffing boxes shall be made of Grade I bronze or cast iron. The width of the packing shall be at least $\frac{1}{4}$ in., and the depth of packing space shall be at least four times its width. Glands shall be made

of solid bronze or bronze-bushed cast iron. They shall be properly secured to prevent rotation with the operating nut. Gland bolts or studs shall be made of either Grade II, III, or IV bronze or rustproofed steel. They shall be of not less than ⅜-in. diameter if bronze, or not less than ½-in. diameter if steel.

Sec. 6—Painting and Marking

6.1. *Coating.* All iron parts of the hydrant, inside and outside, shall be thoroughly cleaned and thereafter, *unless otherwise stipulated,* all surfaces inside and outside (except the exterior portion above the ground line) shall be coated with asphalt varnish (Sec. 4.11). They shall be covered with two coats, the first being allowed to dry thoroughly before the second is applied.

6.2. *Shop coating above ground line.* The outside of the hydrant above the finished ground line shall be thoroughly cleaned and thereafter painted in the shop with two coats of paint of a durable and weatherproof composition (Sec. 4.11) which shall produce a surface to which later coats of paint having a linseed oil or other approved base will readily adhere. The color or colors to be used shall be as specified by the purchaser.

6.3. *Marking.* All hydrants shall have permanent markings identifying the manufacturer by name, initials, or abbreviations in common usage, and designating the size of the main valve opening and the year of manufacture. Markings shall be so placed as to be readily discernible and legible after hydrants have been installed.

Sec. 7—Workmanship

7.1. All foundry and machine work shall be done in accordance with standard good practice for the class of work involved; in conformance with approved drawings, if required; and as approved by the inspector representing the purchaser. When assembled, hydrants manufactured in accordance with these specifications shall be well fitted, smooth operating, and watertight.

7.2. All parts shall conform to the required dimensions and shall be free from defects which will prevent proper functioning of the hydrant.

7.3. All machined parts shall be made to template or gage.

7.4. All joints shall be faced true and shall be watertight when subjected to the water pressure for which the hydrant is designed.

7.5. All iron parts receiving bronze mounting shall be made true and smooth, and the bronze mounting shall be finished to fit.

7.6. All castings shall be clean and sound, without defects which will impair their service. No plugging, welding, or repairing of such defects will be allowed.

7.7. All like parts of hydrants of the same model and size produced by the same manufacturer shall be interchangeable.

Sec. 8—Hydrostatic Test

Hydrants for a working pressure of 150 psi or less shall be subjected, after assembly, to two shop tests under a hydraulic pressure of 300 psi. One test shall be made with the whole interior of the hydrant under pressure; and another with the main valve closed and the footpiece under pressure from the inlet side. Under the above test procedure, there shall be no leakage through the main valve, drain valve, or stuffing box, nor through the castings or the joints of the assembled hydrant. Leakage or other imperfec-

tions found in either test shall be corrected before the hydrant is accepted.

Sec. 9—Inspection

9.1. All work under these specifications shall be subject to inspection and approval by the purchaser's duly authorized engineer or inspector, who shall at all times have access to all places of manufacture where materials are being produced or fabricated or where tests are being conducted, and who shall be accorded full facilities for inspection and observation of tests. Any hydrant or part which he may condemn as not conforming to the requirements of these specifications shall be made satisfactory or shall be rejected and replaced.

9.2. If the purchaser has no inspector at the plant, the manufacturer shall, if so requested at the time the order is placed, certify that the required tests on the various materials and on the completed hydrant have been made, and that the results of all tests conform to the requirements of these specifications.

Sec. 10—Preparation for Shipment

Hydrants shall be complete in all details when shipped. The manufacturer shall use due and customary care in preparing them for shipment, so that no damage due to the manufacturer's negligence will occur in handling or in transit. Hydrants must be drained and completely closed before shipment.

APPENDIX

Characteristics of National Standard Fire-Hose Coupling Screw Thread

Basic dimensions of National (American) Standard hose coupling screw threads are shown in the following tabulation. The complete document (ASA B26) may be obtained at a price of 30 cents per copy from the American Society of Mechanical Engineers, 29 West 39th Street, New York.

1	Nominal inside diameter of hose coupling	2½	3	3½	4½
2	Number of threads per inch	7½	6	6	4
3	Total length of threaded part of coupling and hydrant nipple, external thread	1	1⅛	1⅛	1⅛
4	Distance from face of nipple to start of second turn	⅛	7/16	7/16	7/16
5	Depth of coupling swivel to washer seat	11/16	1 7/16	1 7/16	1 7/16
6	Distance from face of coupling swivel to start of second turn	3/16	¼	¼	¼
7	Depth of thread of coupling swivel	11/16	11/16	11/16	11/16

All dimensions given in inches.
Outer ends of external and internal thread should be terminated by the "Higbee Cut" on *full thread* to avoid crossing and mutilation of thread.

Specifications for

Uniform Marking of Fire Hydrants

The American Water Works Association, recognizing that the adoption of a capacity marking scheme by any water department is optional, herewith provides the following uniform color scheme for painting hydrants rated in terms of their relative capacity.

1. Hydrants are classified as follows:

Class A: Hydrants that on individual test usually have a flow capacity of 1,000 gpm or greater.

Class B: Hydrants that on individual test usually have a flow capacity of 500 to 1,000 gpm.

Class C: Hydrants that on individual test usually have a flow capacity of less than 500 gpm.

Capacities are to be rated by flow measurements of individual hydrants at a period of ordinary demand. When initial pressures are over 40 psi at the hydrant under test, the rating is to be based upon 20-psi residual pressure, observed at the nearest hydrant, connected to the same main, from which no water is being drawn. When initial pressures are less than 40 psi, residual pressures shall be at least half of the initial.

2. The following is the capacity-indicating color scheme:

2.1. *Public hydrants.* All barrels are to be painted chrome yellow except in cases where another color is desired. The tops and nozzle caps of the classes as outlined in Sec. 1 are to be painted as follows:

Class A—green
Class B—orange
Class C—red

2.2. *Private hydrants.* Within private enclosures, the marking is to be at the discretion of the owners. When in public streets, they should be painted to distinguish them from public hydrants.

3. All location markers for flush hydrants should carry the same color background as stated above for class indication, with such data stenciled or painted thereon as may be deemed necessary.

4. The colors shall signify only the approximate capacity of the individual hydrant as tested alone and not its capacity when more than one hydrant in the vicinity is in use. The marking of the hydrant is not to be considered as in any way guaranteeing the capacity indicated by the color.

NOTE: These specifications were adopted by the American Water Works Association at its 1937 Convention at Buffalo and were originally published in the April 1937 JOURNAL, p. 449.

The standard color scheme duplicates, in essentials, similar plans adopted by the Maine Water Utilities Assn. in 1929, by the New England Water Works Assn. on Mar. 21, 1934, and by the National Fire Protection Assn. on May 14, 1936.

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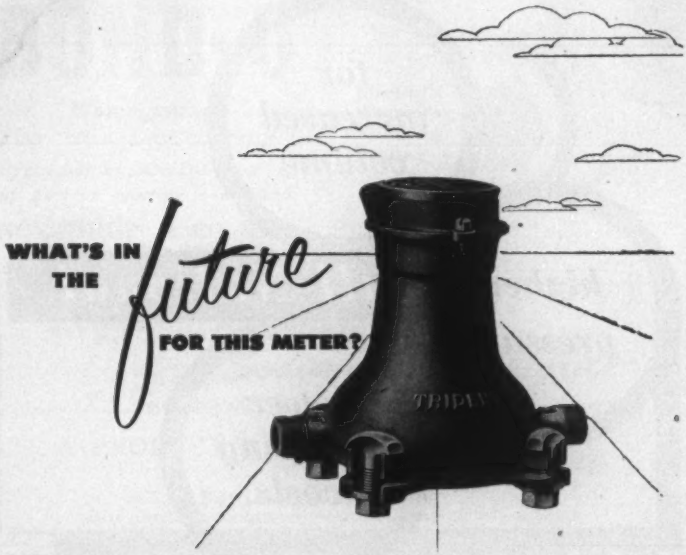

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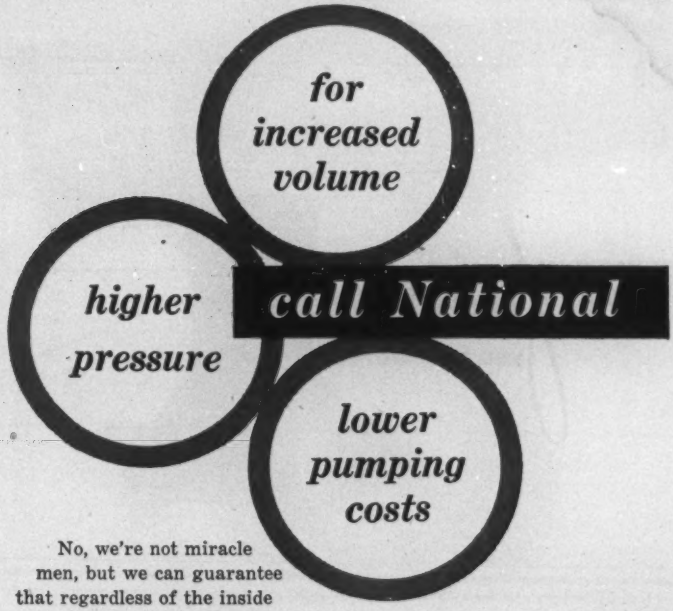

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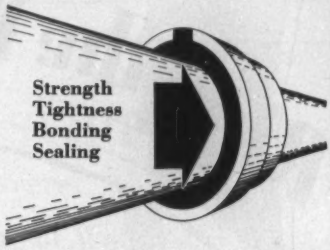

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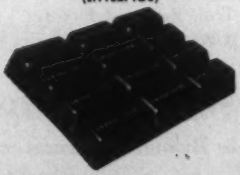

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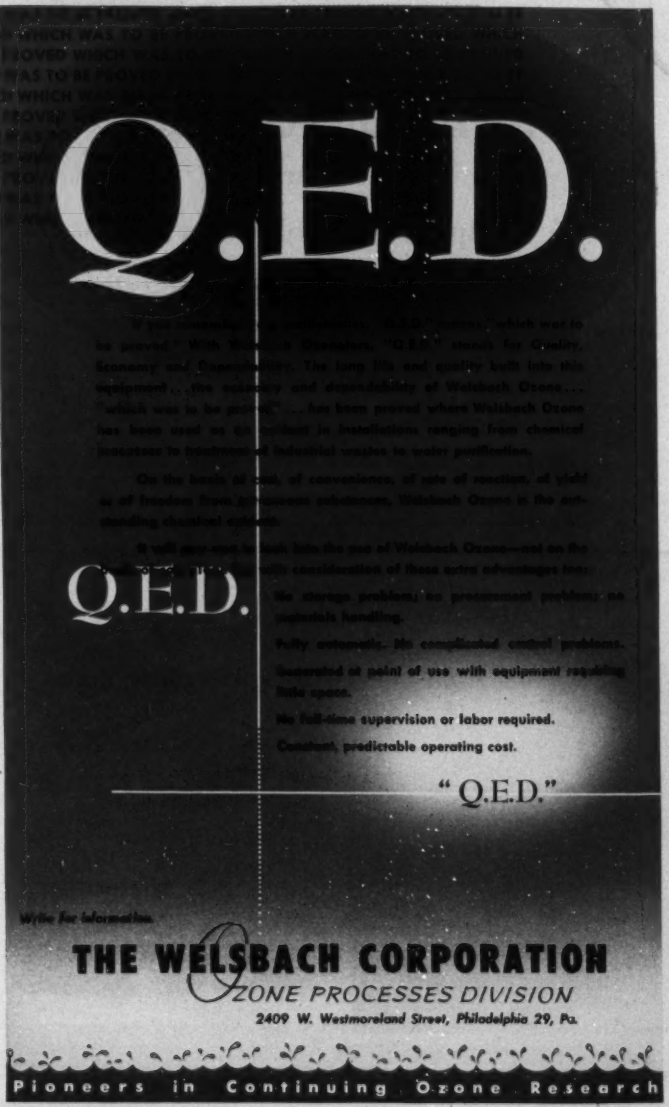
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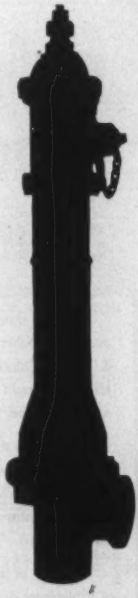

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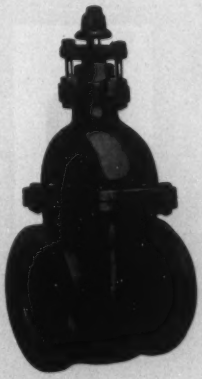

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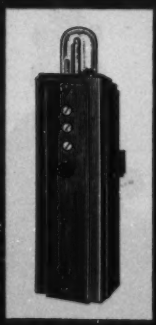

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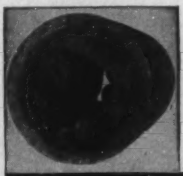

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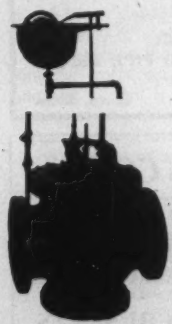

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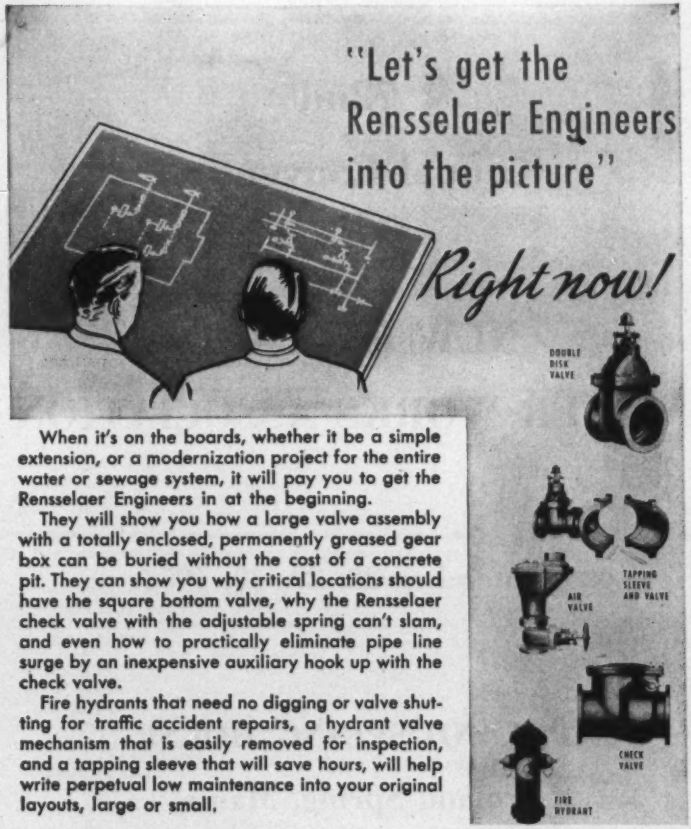

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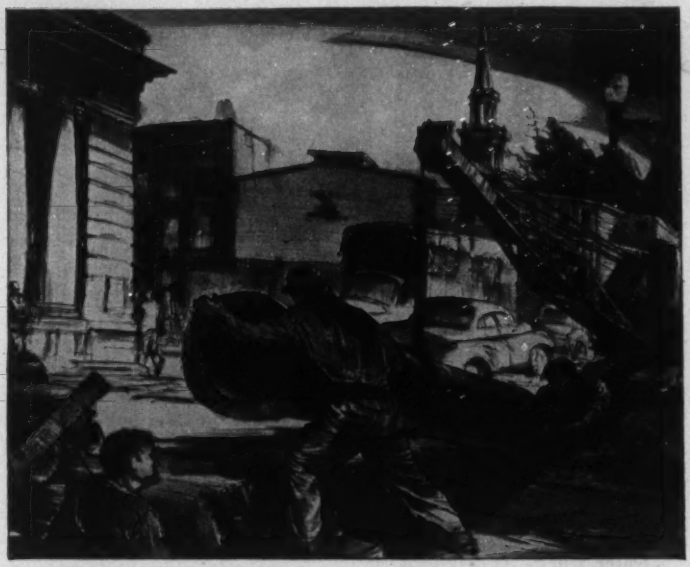

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